HAZARD EVALUATION AND PROCEDURES FOR WORKING IN INACTIVE MINES

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

HAZARD EVALUATION AND PROCEDURES FOR WORKING IN INACTIVE MINES

DRAFT

by

Clarence E. Ellis

Intermountain Field Operation Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

CONTENTS

Page

Introduction.. 1

Background.. 1

Purpose... 2

Acknowledgments... 3

Hazards... 3

Attitude.. 3

Evaluation.. 4

Procedures.. 4

Animals... 6

Evaluation.. 8

Procedures.. 12

Rock falls ("cave-ins")... 12

Portal areas.. 15

Evaluation.. 19

Procedures.. 27

Areas of geologic weakness.. 31

Workings along a weak zone.. 31

Evaluation.. 32

Procedures.. 39

Weak rock units... 39

Evaluation.. 39

Procedures.. 40

Workings crossing weak zones.. 40

CONTENTS—Continued

	Pag
Evaluation	40
Procedures	47
Areas of blasting caused weakness	47
Evaluation	54
Procedures	54
Explosives	54
Evaluation	55
Procedures	55
Falls	58
Evaluation	61
Procedures	69
Falling objects	81
Evaluation	81
Procedures	94
Gases	94
Carbon dioxide	96
Hydrogen sulfide	97
Methane	100
Nitrogen	100
Nitrogen oxides and carbon monoxide	102
Sulfur dioxide	103
Oxygen deficiency	103
Procedures	105
Radiation	106

CONTENTS--Continued

Page

Radon gas ... 107

Evaluation ... 108

Procedures ... 111

Water ... 111

Evaluation ... 113

Procedures ... 116

Getting lost ... 120

Evaluation ... 122

Procedures ... 123

Risk assessment ... 124

Conclusions ... 125

References ... 128

Glossary ... 129

ILLUSTRATIONS

Photos showing:

Figure 1. Going underground in sneakers instead of hard toed boots is a sign of poor attitude ... 5

2. Bats are a nuisance when they fly around trying to escape ... 7

3. Scorpions or spiders may be found partially underground ... 9

4. Throwing rocks inside the adit can frighten an occupant, alerting you to its presence ... 10

5. Animal's nests may be found far from the portal ... 11

6. Rattlesnakes are not uncommon near portals ... 13

7. Eyes reflecting your light may be the first indication an animal is underground with you ... 14

ILLUSTRATIONS--Continued

			Page
Figure	8.	Broken rock shows through gaps in the lagging..............	16
	9A.	A natural arch has formed here............................	17
	B.	A closer look at the natural arch.........................	18
	10.	This portal is for a haulage level that cross cuts through sound rock..	20
	11.	A portal driven through poorly or unconsolidated material must have timber or concrete support to sound bedrock......	21
	12.	Slope creep has blocked this portal.......................	22
	13.	This portal was driven on a thin vein.....................	23
	14.	This is the portal of a crosscut adit.....................	24
	15.	This crosscut adit was driven through highly fractured rock, yet is in good shape after about 80 years............	25
	16.	This portal was driven just off the structure, but is in an avalanche chute..	26
	17.	Loose rocks are not uncommon even in cross cut adit portals	28
	18.	Proper entry technique is feet first......................	29
	19.	Proper exit technique is head first.......................	30
	20.	A drift along a fault.....................................	33
	21.	Parallel, smooth, slightly open, high angle fractures are conducive to rock fall..................................	34
	22.	A hanging wall slab that is nearly ready to spall off the rib..	36
	23.	A large hanging wall slab that is supported by a post......	37
	24.	A sound back in highly fractured rock.....................	38
	25.	Unusually severe spalling off the rib caused by slaking....	41
	26.	A large backfall from a cross fault.......................	42
	27.	Dry rot is not uncommon but is not always visually obvious as it is here..	43

ILLUSTRATIONS--Continued

			Page
Figure	28A.	When a knife or screwdriver blade can be easily pushed into the wood across the grain the wood is rotten..........	44
	B.	The same effort barely gave penetration with the grain of the wood in this sound timber..............................	45
	29.	For convenience the point of a rock hammer can be pushed (or screwdriver) into the wood..	46
	30.	An extreme case of rot..	48
	31.	This post is so rotten that slabs can be torn off by hand..	49
	32.	Timbers in various states of failure........................	50
	33.	A sound post with cap and wedge firmly in place...........	51
	34.	If you feel you must be in a place like this do not touch the timbers..	52
	35.	Passing through failed and failing timbers................	53
	36A.	A cardboard box of dynamite..	56
	B.	Close view of the beads of nitroglycerin on the surfaces of the dynamite sticks..	57
	37A.	The sill in the foreground felt slightly different, calling attention to the pipe..	59
	B.	The same pipe about 3 ft lower......................................	60
	38.	The man on the ladder cannot visually inspect the rungs below as he descends..	62
	39.	A sheave wheel is ~~evidence of a winze~~ used in hoisting..............................	65
	40.	Proper technique if you must walk, a board, pipe, or rail across a winze..	66
	41.	Proper technique where the size of the opening is unknown..	67
	42.	Technique for crossing a rubble-filled winze...............	68
	43A.	Correct ladder technique...	70
	B.	Incorrect ladder technique...	71

ILLUSTRATIONS--Continued

Page

Figure 44. Many ladders are not firmly fastened in place.............. 73

45A. This ladder was built in three sections, carried 5 mi, and bolted together in the mine.. 74

B. The top of the ladder. The man has his hands on the ribs of the raise to prevent tipping............................ 75

46. Correct technique for walking a narrow, gravelly ledge..... 76

47. Climbing up or down stopes may be possible even though ladders are absent.. 77

48. Work platforms may remain in place and provide access in stopes.. 79

49. These rotten timbers don't have far to fall, but are large enough to cause injury if they do........................ 82

50. Heavy pipe hung by wire attached to wooden wedges.......... 83

51. A raise with wet, rotten timber and ladders is an area to avoid........ 85

52. Almost anything may have been left at landings, ready to fall at some provocation................................ 87

53. Heavy fungus growth generally indicates wet, rotten wood... 88

54. An ore chute filled with rock.............................. 89

55. Generally the rock comes down but the chute doesn't........ 90

56. The heavy timbers of this work platform can fall if disturbed.. 91

57. The timbers above look sound, but are not obviously supported.. 92

58. These large and rotten timbers can pick up enough speed to cause serious injury if they fall.......................... 93

59. The man climbing will kick down some rock.................. 95

Fix to match fig. 60A. A hand pump and stain tube will detect low concentrations of toxic gases... 98

B. The stain tube reads about 0.08%............................ 99

ILLUSTRATIONS--Continued

Page

Figure 61. An oxygen-methane detector in use........................ 101

62A. A battery-operated air pump being used to test for radon daughters.. 109

B. The filter is placed in the tube ~~on~~ in the ~~right~~ center, which is the sensing unit of a scintillometer.......................... 110

63. There is a water-filled winze in the foreground............ 112

64. Running water on a gravelly sill will not hide any hazards. 114

65. Deep water may require hip or chest waders.................. 115

66A. Probing deep water in front of you is advisable............ 117

B. The pipe on the sill is easy to see before any mud is stirred up... 118

67. A hoist drum. There should be a winze close by............ 119

68. The left rib swells and flows when wet....................... 121

69. Uncommon hazards exist in some mines....................... 127

UNITS OF MEASURE ABBREVIATIONS USED IN THIS REPORT

move up here

less sp. here

°	degree
ft	foot
hr	hour
in	inch
mR/hr	milliRoentgen per hour
%	percent
lb	pound
lb/sq ft	pounds per square foot
wk	week
yr	year

HAZARD EVALUATION AND PROCEDURES FOR WORKING IN INACTIVE MINES

INTRODUCTION

Inactive mines are, on the one hand a potential hazard to the general public, but on the other hand a potential source of valuable information to geological and mining professionals. A safety training program is essential for anyone going to work in an operating mine, yet inactive mines are generally more hazardous than operating mines. On the job training by an experienced co-worker, if available, is the only good way of learning how to safely work in inactive mines. The printed word is a poor substitute for on the job training, but it can be used to begin, and to aid, the learning process.

The term inactive mine, as used here, is defined as any underground working which is not being currently operated. For our purposes, such distinctions as whether it is a mine or prospect, or whether it is inactive or abandoned, have no meaning. These are definitions that are not relevant to the real world of staying alive and healthy in any given underground working.

Background

Since the Wilderness Act became law in 1964 the Bureau of Mines has been engaged in evaluating the mineral resources on those lands in or under consideration for inclusion in the wilderness system. Examining such inactive mines as are present in these areas is a necessary part of that job. During the years subsequent to the Wilderness Act, the Bureau of Mines Intermountain Field Operations Center (IFOC) has been engaged in this work, and similar evaluations on Indian Reservations. There have been no underground accidents among any of the 10 to 30 persons assigned to this task at any given time.

I have personally examined about 300 inactive mines, and would estimate that personnel at IFOC have examined well over 3,000. The worst injuries have

been skinned knuckles. Some hundreds of inactive mines were not examined because the hazards appeared too great.

Purpose

Entering inactive mines is necessary if some jobs are to be well done. There are no agencies that claim jurisdiction over inactive mines, as there are for active mines. There are no standard rules or procedures set down to follow. The safety procedures required of personnel working in operating mines are not entirely appropriate in inactive mines because the conditions encountered are generally different.

Entering inactive mines is not safe, and it cannot be made safe. There are no trained and equipped rescue teams available if something goes wrong. Other rescue teams will not and should not go underground as a general policy. You are on your own. You must determine if your purposes justify the risk of entering, and if you choose to enter you must do so with full knowledge of what you are doing.

To work in inactive mines with acceptable safety you must (1) recognize the hazards involved, (2) evaluate those hazards, and (3) know the techniques for avoiding those hazards or coping with them. This paper is intended to allow personnel of the Bureau of Mines, Bureau of Land Management, and U.S. Forest Service who must evaluate mineral occurrences on a regional or claim-by-claim basis to accomplish their job as well and as safely as is possible. It could also be useful to a variety of geological professionals in the private sector. A basic knowledge of geology is assumed, but the language is intended to be understood by professionals who did not have course work or experience in mining, rock mechanics, etc. A brief glossary of mining terms is included. This report is not intended for use by the general public.

Acknowledgments

The on-the-job supervision of Alec Lindquist is the primary reason for the safety record at IFOC. Lindquist grew up working with his father in his small mine. He later managed ASARCO's mine at Leadville, CO. The knowledge acquired in this broad, extensive experience was available to all of us who worked with Mr. Lindquist, and we in turn have passed the knowledge gained to our co-workers.

Additional knowledge has been a gained from personnel at the Mine Safety and Health Administration.

Photographs used in this report are of and by Mineral Land Assessment (MLA) personnel. C. Ellis, B. Hannigan, J. Thompson, and S. Tuftin were taken specifically for this report. The facial expressions in the photographs do not, unfortunately, always reflect the appropriate gravity for the situation illustrated. Many photographs were staged to show a hazard or degree of hazard that did not exist.

HAZARDS

Hazards to be aware of when entering inactive mines are: improper attitudes, animals, rock falls, explosives, falls, falling objects, gases, oxygen deficiency, radiation, water, and getting lost. Evaluation of the first three begins outside the portal and must continue as long as you are underground. The next seven hazards may be present anywhere beyond the portal. Getting lost is possible in larger mines.

Attitude

An improper attitude toward underground work can negate the best safety procedures and equipment, and predispose you to succumb to the hazards present in the mine. It can be the catalyst that brings about an accident.

Evaluation

The hazard of an improper attitude is best examined prior to going underground. Show-off attitudes, yielding to peer pressure to show you aren't chicken, "it can't happen to me" (fig. 1), "I know it all because I've done this for years" are all obviously dangerous attitudes. Horseplay is definitely out of place.

More subtle is an individual's response to perceived danger. Some pretend there is no danger. Some must place the responsibility for their safety on someone else. Some individuals are incapable of performing at their usual level of ability.

The best attitude is a constant state of fear that makes one alert, observant, and ready for action. However, a state of fear that makes one tense, worried, shaky, or gradually wears down the nerves, is a signal to not go underground.

The proper attitude will ensure that you take along and use the necessary equipment even if it is: too heavy, too big a nuisance, or has never been needed before.

third order head space

Procedures

Training under an experienced person will help form the correct attitude, and can be expected to counteract the problems listed previously when the individual with the attitude problem can recognize they have that problem. The more subtle attitude problems--response to fear--are most likely an unchangeable part of an individual's make up, and when recognized should be accepted as a clear signal not to go underground. Because many people will not recognize and accept their own attitudes for what they are, it is sometimes necessary for a more experienced person to do some serious training.

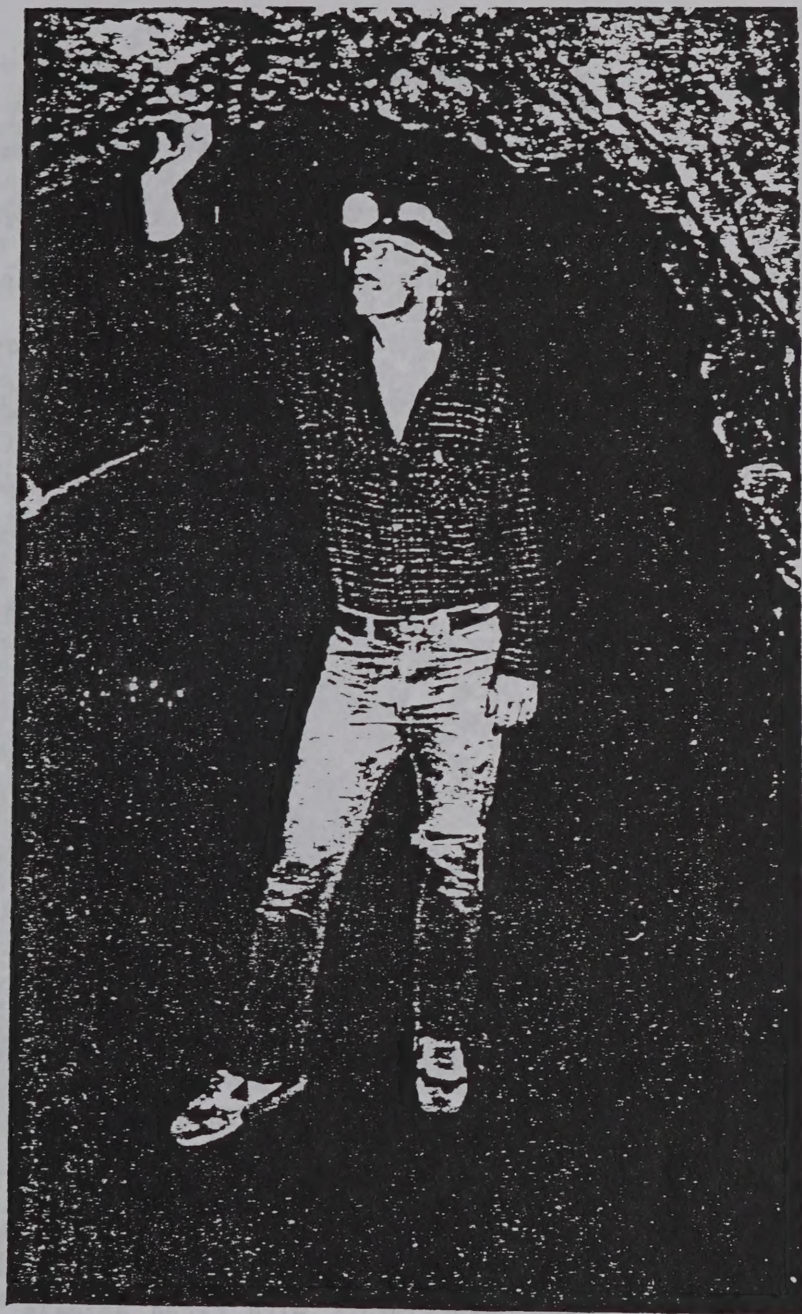


Figure 1.--Going underground in sneakers instead of hard toed boots is a sign of poor attitude. ("It can't happen to me. I've never had a hard rock fall on my toe. I'm careful.").

and possibly dictate that some people not go underground if they cannot or will not learn.

Animals

Nearly every creature that will fit through an underground opening will occasionally be found underground. Tracks of cows, burros, bears, javelina, foxes, and bobcats have been observed inside portals. Many of these, such as cows, are not generally considered dangerous, however, if you enter behind them they feel cornered and threatened, and will generally panic and run over or around anyone in the way while trying to escape.

Other animals may use mines for dens while raising their young. Even small animals such as foxes and ringtailed cats can be dangerous when defending their young. Bears, cougars, skunks, and rattlesnakes are obviously potentially harmful.

Birds, bats, and rats are frequently encountered, but usually escape while doing no harm (birds, bats) (fig. 2), ignore you and sleep (bats), or hide (rats). They seldom cause more than fright.

Bats are often feared as a source of rabies, and rabid bats are not uncommon. In isolated cases rabid bats have bitten people, usually people who were handling the bats or trying to shoo them away from themselves. Actual attacks by bats are exceedingly rare. One rabies case has been traced to prolonged exposure of a spelunker to the droppings (guano) from a huge colony of bats in a cave. Experiments with caged animals indicated the rabies was transmitted in an aerosol form that was inhaled by the victim. Lung diseases can be contracted by bat (or bird) guano, generally in a humid environment (John Poppy, Colorado Dept. of Health, Oral Communication, April 1988).

Figure 2.--Bats are a nuisance when they fly around trying to escape. They may be annoying or frightening, but they are not a direct hazard. However, a thick layer of guano can hide a boarded over winze, and dry guano will yield a dust which is irritating to the lungs and could carry diseases.

Evaluation

— to much space

The purpose of your evaluation in this case is to determine if an animal is present. Any animal should be assumed dangerous if encountered underground. At the portal, look for tracks or fresh droppings inside or leading inside. If there is an animal odor, decide if it is fresh or stale. Look for fur rubbed off on edges of the opening, and for bones, skin, feathers, and other remains of a predator's meals inside the portal. All of these indicate recent use but do not insure present occupancy. Conversely, the mine may be occupied and none of these be present. Spiders and scorpions will leave no obvious sign of their presence, but in warm climates will often inhabit the debris near the portal (fig. 3).

While still outside, and not blocking the portal, throw rocks inside (fig. 4) if there are no explosives within range of your rocks. After each rock, listen for any sound. Be ready to move aside rapidly if the occupant flushes. It in snake country throw lots of rocks into the rubble and timbers just inside the portal, including any timbers overhead. Listen for rustling or the buzz of an annoyed rattlesnake. Finally, reflect sunlight inside with your Brunton mirror, if possible. This light is far brighter than any cap lamp and will allow you to see evidence of occupancy beyond the portal; it may also disturb an occupant enough for it to announce its presence.

Nests, droppings, and bones have been found hundreds of feet from the portals of inactive mines (fig. 5). Coyotes, javelinas, rattlesnake, skunks, pack rats, ringtailed cats, jack rabbits, squirrels, birds, and bats have been encountered underground, sometimes several hundred feet from any glimmer of light. Wet mines are rarely occupied, but damp ones may be.

Figure 3.--Scorpions or spiders may be found partially underground, particularly among timbers and rubble near the portal.

Figure 4.--Throwing rocks inside the adit can frighten an occupant, alerting you to its presence before it becomes a hazard. Piles of leaves and trash near the portal should be targeted. Remember to listen for the buzz of an annoyed rattlesnake.

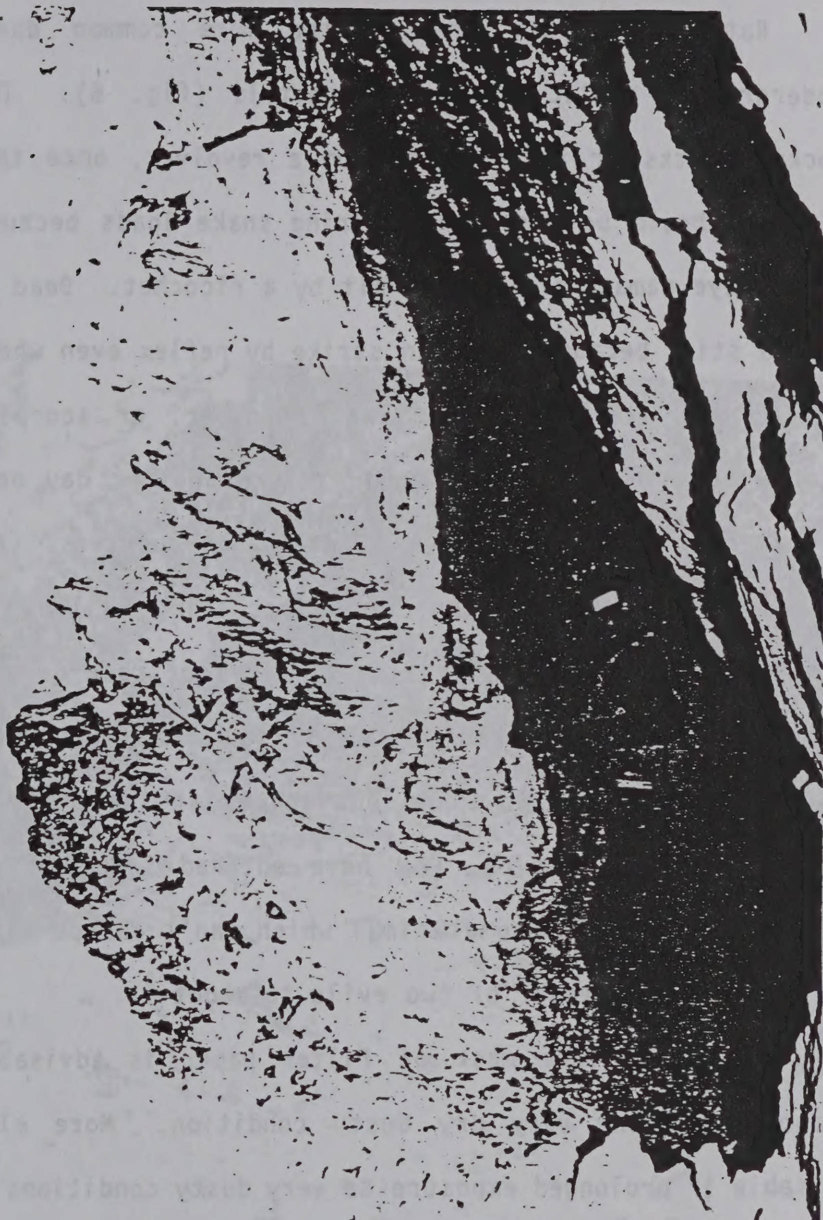


Figure 5.--Animals nests may be found far from the portal, as may remains of meals. The latter may indicate the size and degree of threat posed by the creature if encountered underground. This is a pack rat's nest.

Procedures

Rattlesnakes are one of the more common dangerous creatures found underground, particularly near portals (fig. 6). They can be killed with rocks, sticks or snake shot from a revolver, once they are located. Safety glasses should be worn while firing snake loads because even the tiny pellets can do eye damage if you are hit by a ricochet. Dead snakes should be removed with a stick because they can strike by reflex even when dead.

If any creature but a snake, spider, or scorpion is present, and not scared out (fig. 7), you should return another day or night. If you disturb it often enough it may move to different quarters. Attempts to shoot larger animals present grave danger of ricocheting bullets, ear damage from muzzle blast in a confined space, possible fall of rock or debris due to concussion, and attack by a panicked animal if you don't kill it, or if there are more than one. Shooting anything but snakes at the portal should not be done if avoidable. If, however, you have entered some distance believing the mine vacant, and surprise some animal which can't escape without going through you, it might be the lesser of two evils to shoot it.

A simple face mask of filter paper is advisable when walking in dry guano or in any very dry dusty condition. More elaborate face masks are adisable if prolonged exposure to very dusty conditions is anticipated.

Rock falls ("cave-ins")

Rock falls are usually referred to colloquially as cave-ins. A more correct term is back fall. They are most common at (1) portals, (2) areas of geological weakness, and (3) areas of blasting caused weakness, however they can occur anywhere underground.

A common misconception is that timber (or rock bolts, steel, or concrete) is used to support the total rock mass overhead. None of these means of

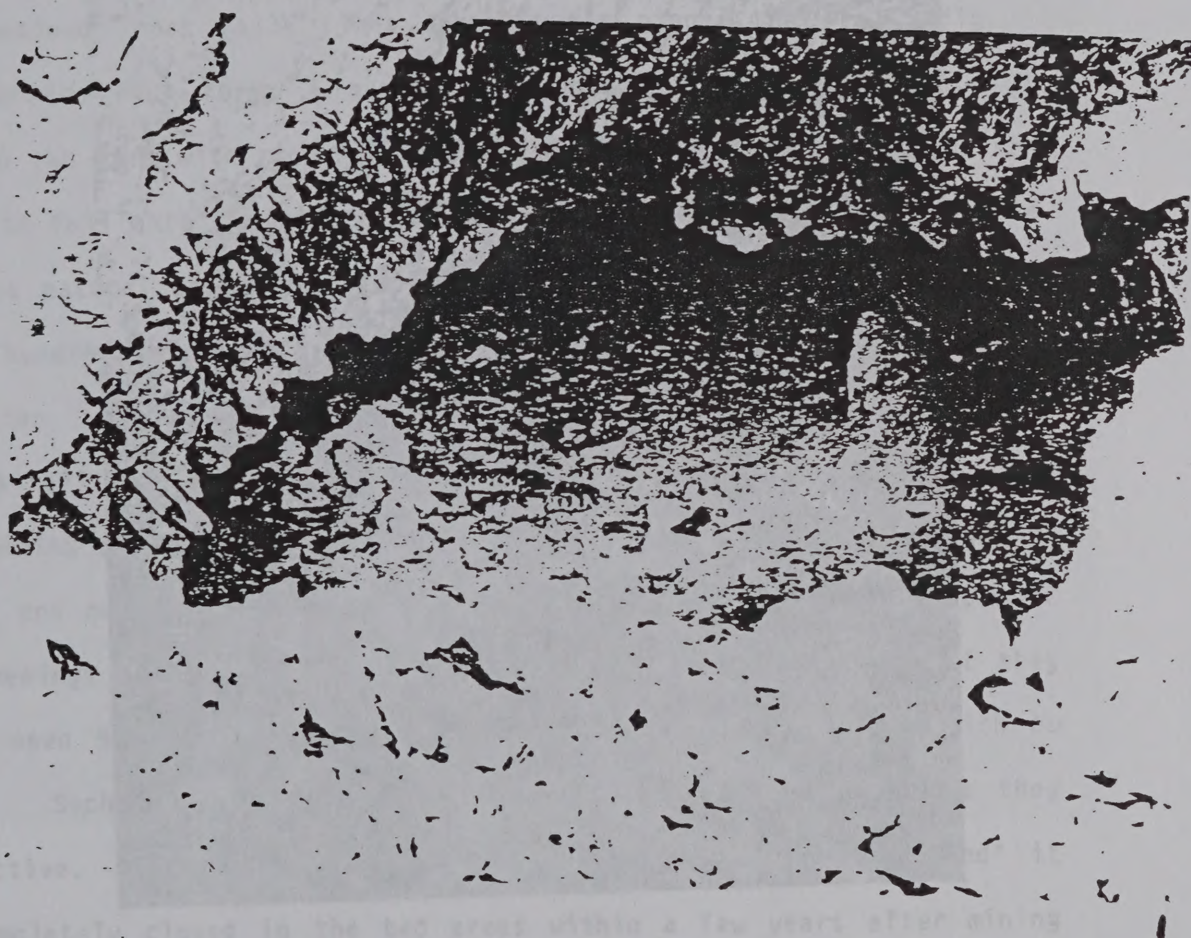


Figure 6.--Rattlesnakes are not uncommon near portals, and can be found farther inside.

Figure 7.--Eyes reflecting your light may be the first indication an animal is underground with you. When the eyes are this high off the sill you should assume it is a large animal and depart. It <u>could</u> be a small animal on a ledge, but if it isn't you could be in trouble.

support have the strength to support the rock mass except at the portal wh the rock thickness is not great. A mere 100 ft of overburden has a weight over 40 tons/linear foot across a 5 ft passage.

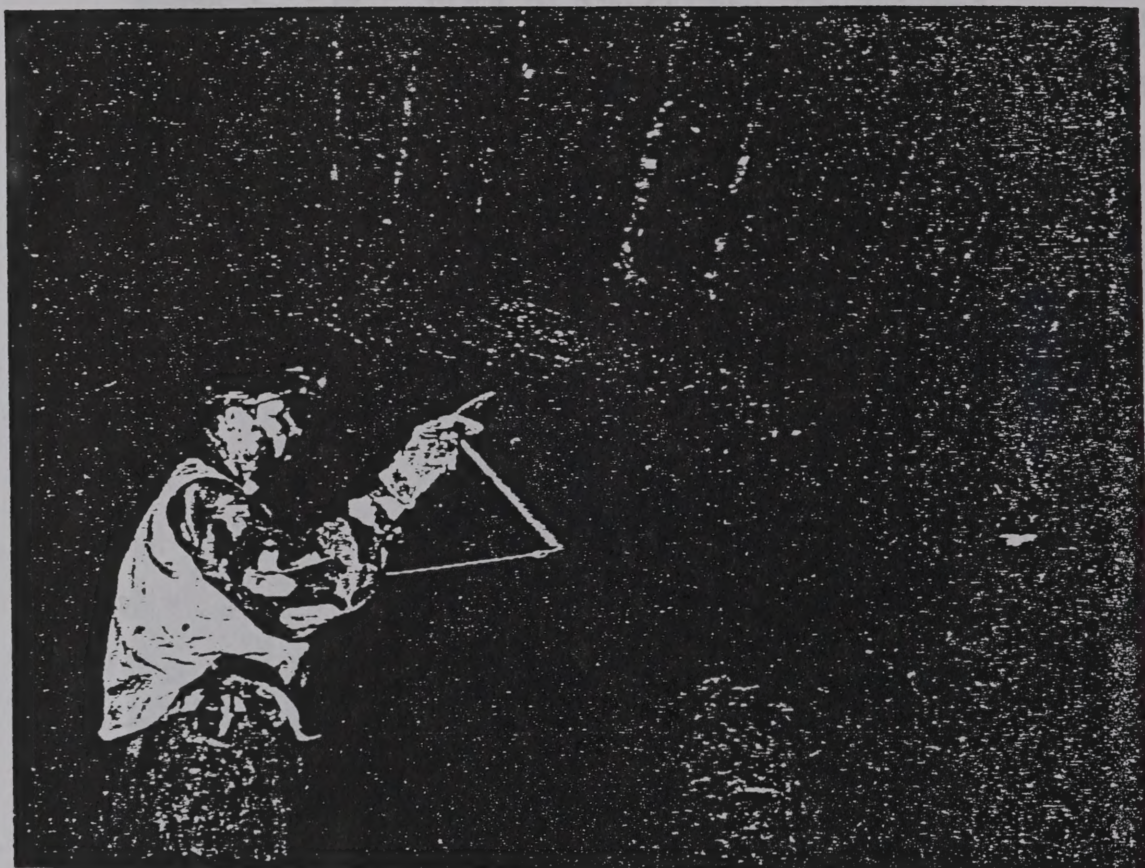
Where rock fracture density, by any combination of blasting and natur causes, is high, the miner could bar pieces down continually. If the materi dislodged is not "ore" the miner would put in timber and lagging instead enduring continual rock fall. This supports the pieces that fall (fig. until the broken rock forms a natural arch that is self supporting. Tl natural arch can form with no support from the timber. It is common for sor loose rock to fall onto the timber leaving a gap between the timber-supporte rock and the natural arch (fig. 9A, B). Loading on the timber is generall only a few hundred lbs/sq ft. This load can be supported until the timber i totally rotten. Removal of a key to the arch, which could be a timber, ca cause a back fall.

Some mining districts have tectonic forces that may exceed the weight oi overburden, and may have any orientation. Artificial support may be able tc maintain openings for years in these mines, but it is not likely that they would stay open 50-80 years (the age range of most inactive mines) with no maintenance. Such mines rarely stay open (in the stressed areas) once they become inactive. Generally speaking, if a mine really has "bad ground" it will be completely closed in the bad areas within a few years after mining ceases.

third and spac

Portal areas

The portal of an inactive mine is generally hazardous--often the most hazardous part of the mine as far as back falls are concerned. The exceptions



21

Figure 8.--Broken rock shows through gaps in the lagging. These timbers are obviously wet and probably rotton. The rock hammer is being used as a pointer. You should not test timbers you are under.

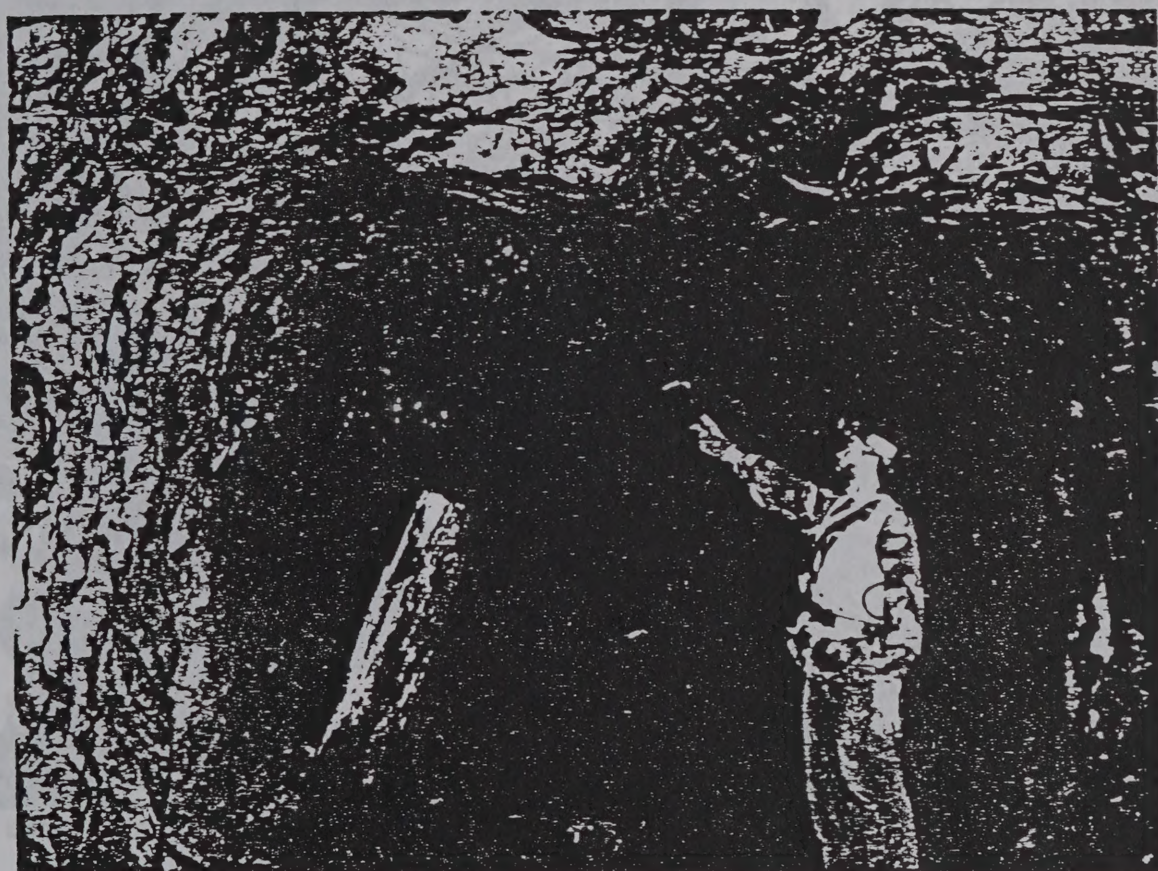


Figure 9A.--A natural arch has formed here, as shown by the space between the timber and the back. This is a rather wide opening for formation of a stable natural arch.

Figure 9B.--A closer look at the natural arch, which is obviously unsupported. The timber does support the lagging and the small rocks that fell as the arch formed.

are mines portalled in a massive rock face with no structural weakness and r soil cover (fig. 10). In many cases it has been 50-100 years since the min was active, during which time considerable debri can accumulate.

Typically an adit is driven into a slope with some depth o unconsolidated material--soil, talus, screen, fractured bedrock--above soun bedrock. Once excavation begins the unconsolidated material is no longe supported and begins to move downslope (slope creep). To avoid constant clean-up it is common to use timber support at the portal (fig. 11). When mining--and cleanup--ceases there will be slow build-up of rock and soil in front of the portal; deterioration of the timber and heavy rain storms will accelerate the process. Eventually the portal will be covered completely (fig. 12). These mines are generally referred to as caved-in when in fact they merely had a load of colluvium dumped in front of the entrance.

Evaluation

Prospects are often driven on a vein or fault. If the prospect evolves into a mine this may remain the only entrance. These portals are subject to both slope creep and rock fall from the vein or fault, and generally are in poorer condition than portals driven to intersect the vein or fault (fig. 13-14). It is easy to dislodge rocks from portals on veins or faults. Some portals were not driven on weak zones such as a fault, but were poorly located with regard to natural rock fall and snow avalanche chutes (fig. 15-16). Such portals may be nearly blocked, but basically sound. These portals are relatively safe except during storms, when they are very hazardous.

The condition of the rock in the portal, and the nature of the slope above it must be examined to understand what the amount of rock in front of

Figure 10.--This portal is for a haulage level that cross cuts through sound rock. The mine has been inactive for about 50 years, yet the portal is still in good shape.

Figure 11.--A portal driven through poorly or unconsolidated material must have timber or concrete support to sound bedrock. The timbers here were installed about 5 years ago and are already being crushed by slope creep.

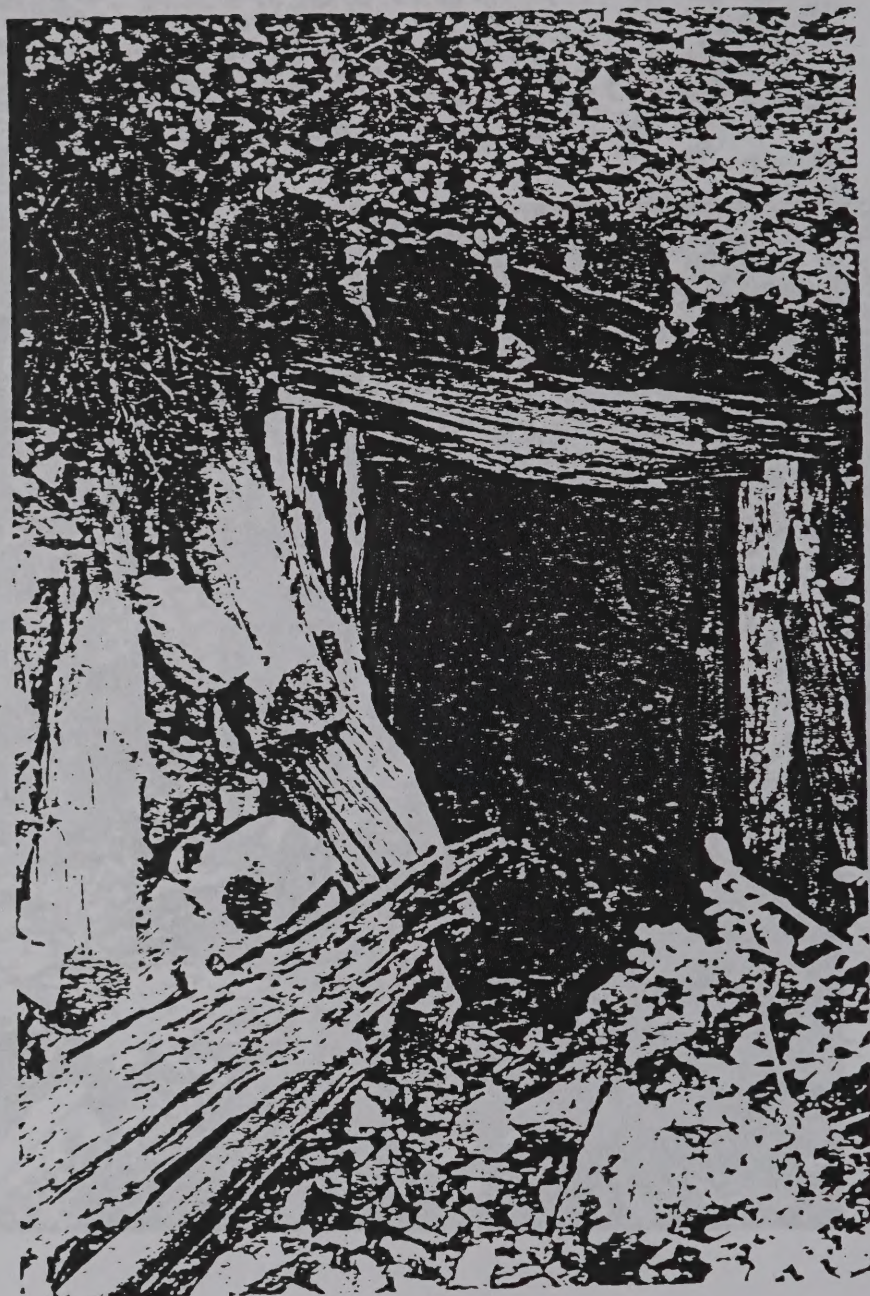
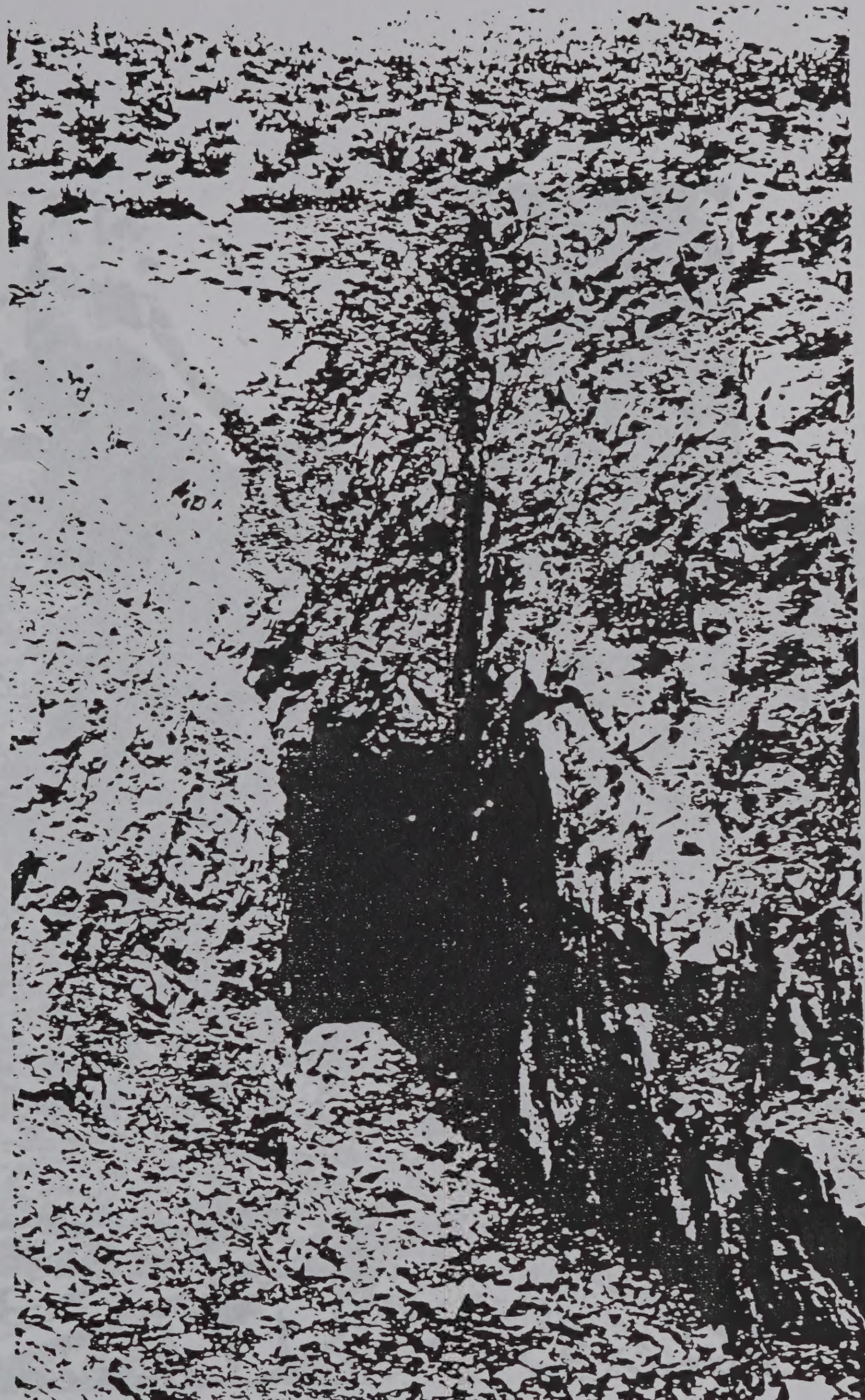


Figure 12.--Slope creep has blocked this portal. The timbers failed underground where soil moisture sped up their decay.



14

Figure 13.--This portal was driven on a thin vein. It was cleaned out 2 years ago. Note the rock on the snow near the portal. That is only a few months accumulation, and this slope is too flat for much slope creep. This rock fall is from the highly fractured rock just left of the vein.

Figure 14.—This is the portal of a crosscut adit. After 30 years of standing idle it is still in good shape.

Figure 15.--This crosscut adit was driven through highly fractured rock, yet is in good shape after about 80 years. It was poorly sited with respect to the talus slope which will eventually cover it. Talus creep is rather steady, and not much affected by storms.

Figure 16.—This portal was driven just off the structure, but is in an avalanche chute. Rock will come down this chute during any heavy rain storm, making it a very unsafe location during storms.

the portal signifies. Knowledge of how long the portal has been open and unmaintained is useful in deciding if additional fall may be expected during the time to be spent underground (fig. 10, 11, 13-16). Heavily fractured and loose rock in the portal always dictates caution (fig. 17).

Procedures

When entering a mine avoid brushing against or bumping the timbers on the back as you can dislodge enough material to injure, pin, or bury yourself if anything is loose. If the portal is partly blocked and difficult to negotiate without contact visually evaluate the apparent rock/soil stability and the condition of any timber. If possible poke and bump the worst looking material from outside with a pole to check its stability. If you can dislodge anything you should keep prodding until all the loose material down, or has blocked the portal completely.* If you want to dig your way in you should first finish knocking down the loose material above.

If the opening is so small you must crawl through, and you decide to enter, it is best to slide in feet first on your back (fig. 18). This minimizes the chance of knocking material down and allows a chance for retreat. When exiting, the tendency is to go on hands and knees (fig. 19); however, most people will have their butt elevated and may bump it on the back. Try to avoid this even if you have to get dirtier and swim up the slope on your belly. On rare occasions you may have to exit face up. Anything you have on your belt or in your vest can catch, so you must be very conscious of what sticks out where, and how far.

---

*The force exerted in prodding should exceed the force you might expect to impose doing your intended activities by a modest amount. The purpose is not to dislodge everything possible.

Figure 17.--Loose rocks are not uncommon even in cross cut adit portals, and should not be disturbed when you are under them.

Figure 18.--Proper entry technique is feet first. He can see where he is going and can kick rocks on any snakes before they can bite him. This was a 6 foot high portal with a sound brow. Slope creep has nearly covered it.

Figure 19.--Proper exit technique is head first, keeping shoulders and hips low enough not to dislodge loose rocks.

If the portal looks questionable, but you decide to enter, the smallest or most agile person should be first in. They should look the portal area over carefully from inside before anyone else enters. Keep movement through the portal to minimum. Get in, do the job, and leave. Don't keep crawling in and out, it just presents more opportunities for knocking rocks down.

Unless you are prepared for excavation of sluffed material and timbering/retimbering, you must try to dislodge loose material at the portal before entering, and try to dislodge absolutely nothing thereafter. It is wise to have a shovel or two inside, particularly if everyone is going in. Leave it near the portal but under sound back.

You can place a long piece of pipe or heavy plastic tube through the portal area so that both ends should remain clear in case of a serious back fall. This will allow fresh air to enter so you can dig yourself out without suffocating in the process.

Areas of geologic weakness

Geologic weaknesses can be faults, veins, or fractured or soft rock units. Mine workings very often followed these zones of weakness because that is where the ore was. The workings often intersect other weak zones such as faults. The greater the inclination of a weak zone above horizontal the more likely there will be rock fall from it.

Workings along a weak zone

Small mine operators have always avoided moving any rock they didn't believe was ore. Consequently they never drove workings through sound rock if they could help it. Timbering was avoided, if possible. The result is that, although a great many workings were driven along weak zones, the truly weak

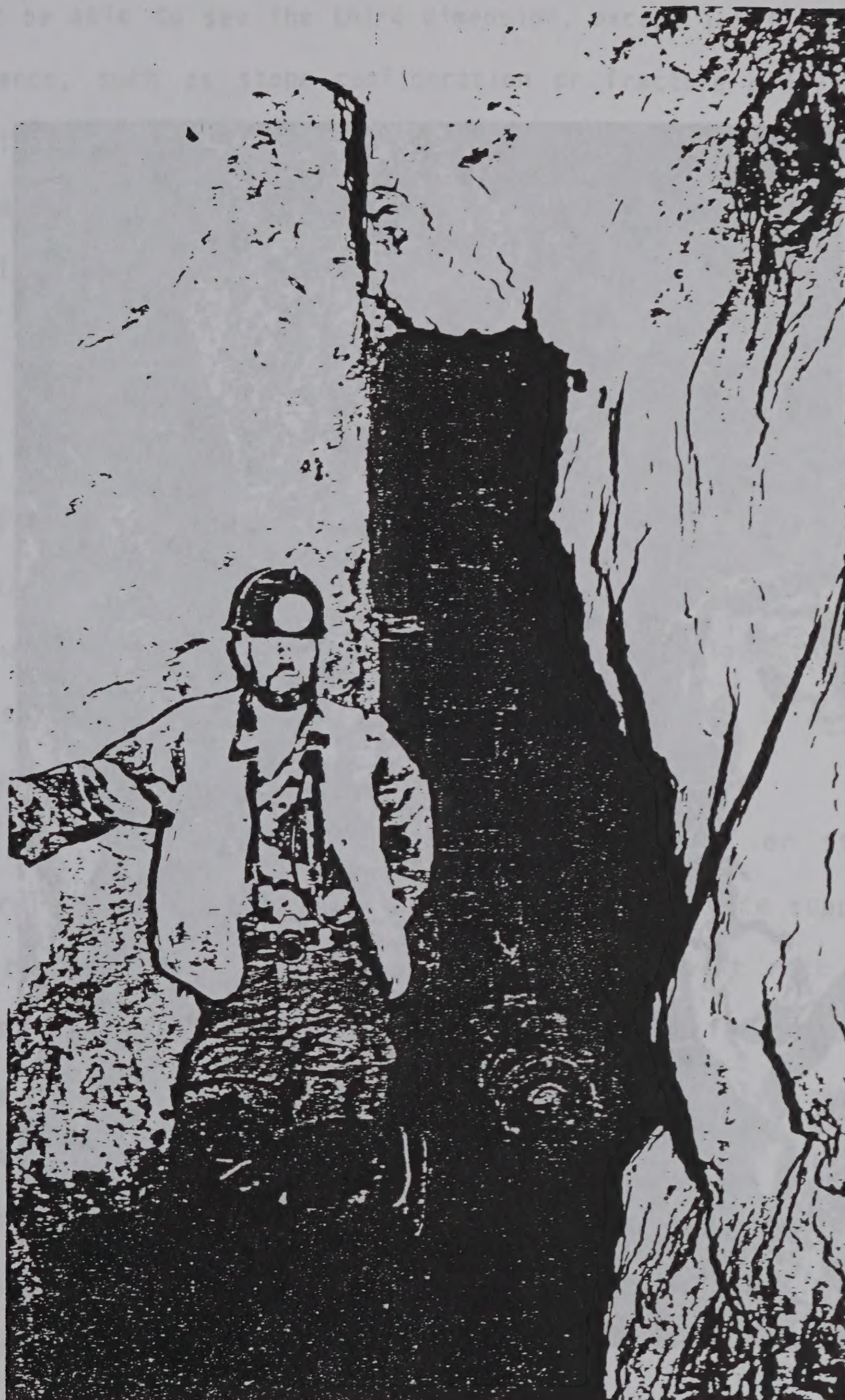
zones in inactive mines are generally completely failed, and thus not open, and the open workings are on zones that are weak relative to the rock mass as a whole, but are fairly stable.

Evaluation.--The mineralizing fluids that deposited the ore minerals followed fractures or permeable beds. This natural permeability may remain and be a conduit for groundwater. Except in very arid regions this ground water movement will aid in slow decomposition of the rock, leading to greater weakness. Wet mines are therefore generally more hazardous than dry mines. The altered rock, even if dry, is often weaker than it was previously.

The most common situation is a working along a fault containing an intermittent vein (fig. 20). Rock adjacent to the fault plane is altered, fractured, and often has clay coatings. Pieces of this fractured, clay-lubricated mass, both wallrock and vein, can fall with little disturbance on your part. If these chunks are smaller than a baseball, your hard hat and hard toed boots offer good protection. A 6 in. cube of rock, however, will weight about 20 lb, and a 1 ft cube will weight about 160 lb. Drop either of those on your boot or hard hat from any distance, and you can expect injury or death.

Continuous smooth fractures, approaching vertical orientation, make good sliding surfaces. Rock fall is thus more likely, and there is a better chance of a large fall. Irregular, discontinuous fractures are more likely to cause wedging of blocks, and have greater internal friction. Rock fall is not as likely.

Lenses of vein or wallrock bounded by smooth fractures are possible sources of large falls, but may be quite stable, depending on whether the lens is wedge-shaped upward or downward, or has parallel sides going up (fig. 21).



32

Figure 20.--A drift along a fault. The smooth fault plane allows fragments of rock to fall out of the back with relative ease. This explains the abrupt step in the back.

Figure 21.--Parallel, smooth, slightly open, high angle fractures are conducive to rock fall. This is the site of a recent back fall.

You probably won't be able to see the third dimension, except locally, so you use indirect evidence, such as stope configuration or fracture orientations elsewhere in the mine.

Workings driven along planes that are not vertical often have loose slabs on the hanging wall (fig. 22, 23) which can fall if pried or hammered on.

Intersections of joints, or joints and bedding planes, can create blocks that are held only by friction. Tight fractures, that would not easily accept a knife blade, are not conducive to fall (fig. 24). Open fractures have less friction, and fall is more likely (fig. 21). Slickensides or damp, clayey surfaces are warnings that natural fall is likely. Thin films of clay on fractures may allow easy sliding, but there are often a few bulges that will wedge the block despite the clay. Thick zones of clay gouge will allow those bulges to plow a furrow and slide.

Stopes often have posts across them. Stopes on vertical or steeply dipping veins generally do not need support, however the posts once supported platforms the miners worked from. To a degree the posts prevent rock spall from the vein walls. The main hazard in this situation is from falling posts, particularly if dry and shrunk, in which case they are very loosely wedged in place and may be easy to dislodge. In stopes flatter than about 60° the posts can also prevent slabs spalling off the hanging wall (fig. 23), but unless the working is very shallow they cannot support the entire hanging wall. These slabs can weigh as much as several tons.

The best indicator of rock fall is a pile of rock below a cavity in the back. Many small piles generally indicate that the working is naturally becoming stable. Large piles indicate that major weaknesses have been present and fall could continue. Remnants of drill holes are clear evidence that

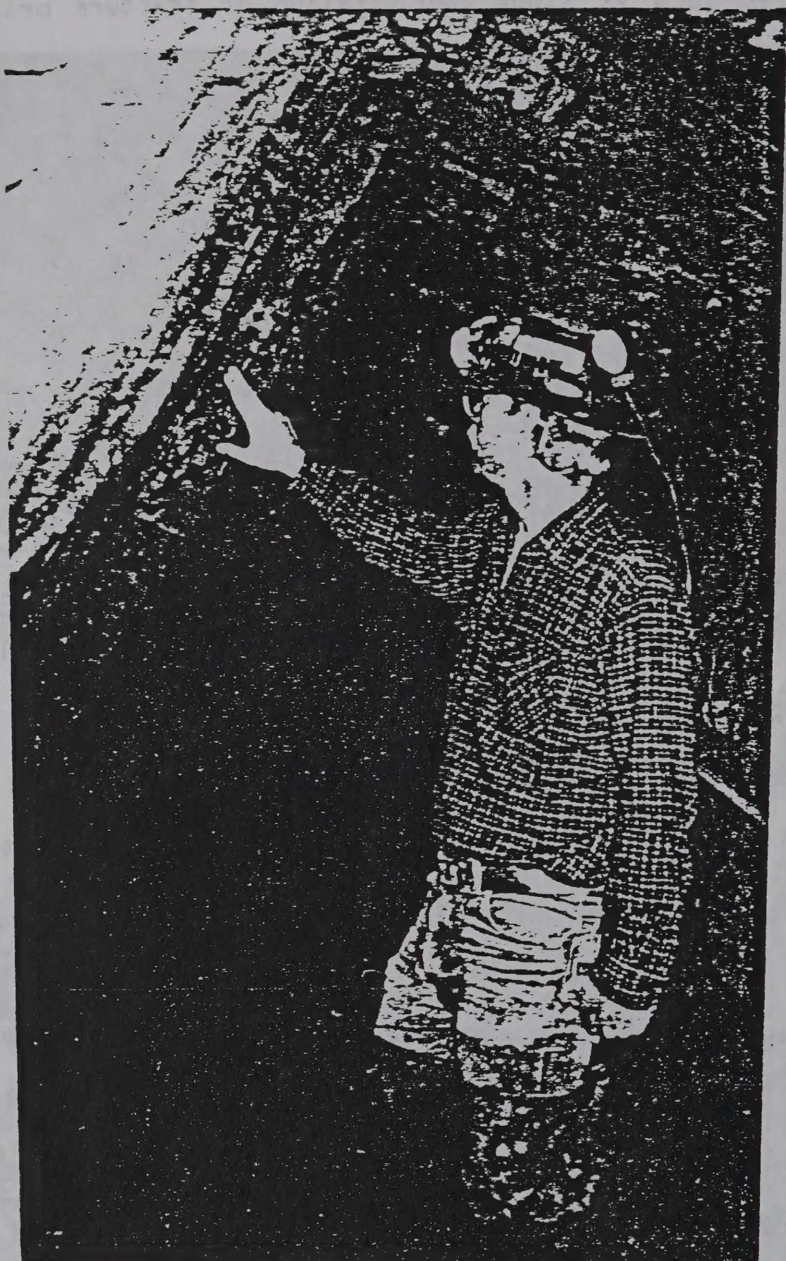


Figure 22.--A hanging wall slab that is nearly ready to spall off the rib. Often they are detectable only by sound when tapped with a hammer. Heavy pounding could break the slab and bring it down, resulting in serious injury.

Figure 23.--A large hanging wall slab that is supported by a post. This slab is so large it would probably sound like solid rock when tapped with a hammer. If dislodged, the consequences could be fatal.

Figure 24.--A sound back in highly fractured rock. The fractures are smooth, parallel, and near vertical, but they are very tight, so back fall is unlikely.

mining, not natural fall, caused a cavity. I have examined a rock fall area caused by a fault intersection in a tailrace tunnel in El Salvador. On three previous occasions rock fall had partly blocked the tunnel, and had been cleaned out by hand to allow the water to flow freely. When I was there the loose rock filled the tunnel to about 8 ft, which was the normal water level. The back was a dome-shaped cavity about 20 ft higher than the tunnel back. The shape of the cavity was that of a stable arch, but the evidence clearly showed that the stability was temporary, and that rock fall would continue.

Procedures.--Careful visual examination of all the evidence is essential. If a long bar is available you can try to pry or knock down loose rock as you would at the portal assuming you are properly equipped, trained, and have a safe pace to stand. This is rarely the case. Beating on the rock with a hammer may tell you by tone, or vibration, or visible movement that the rock is locally loose. Questionable areas are relatively safe to walk by, but sampling should be avoided, because it may dislodge enough rock to cause injury.

If beating or prying causes vibration or movement, including rock fall, do not go under that area unless all the loose rock is first knocked down. In some cases that will mean you don't go there at all.

Weak rock units

Weak rock units include micaceous schists, poorly cemented sandstones, weakly indurated shales, or highly altered rocks. They may crumble and flow on exposure to air or water.

Evaluation.--Weak rock units can generally be gouged by a rock hammer. In general, these rocks fall in small pieces as evidenced by piles of crumbly

rubble. These small falls are not problems by themselves, but may remove support from rocks that can fail in big pieces.

Procedures.--Workings in these rocks should be avoided when the groundwater changes drastically. At such times the rock can crumble from the wetting or drying (slaking) with no action on your part (fig. 25). Unfortunately you seldom know when this is happening, so probably the best you can do is avoid them during or after long rainy periods.

Workings crossing weak zones

Workings in sound rock invariably cross weak zones. Modern practice would be to use timber, concrete, rock bolts, steel sets, or some combination to support the rock. Old time prospectors and small miners were too frugal to use timber support unless they were sure it was absolutely essential. As a consequence there is generally rock fall from these unsupported weak zones in inactive mines.

Evaluation.--Rock fall that completely blocks the working presents no problem; you simply are blocked from the danger zone by the fallen rock. More often you can crawl up the pile into the hole left by the fall, and slide down the other side (fig. 26). This must be done with care, not only to avoid further rock fall, but because water or heavy gas (see gases section) may be ponded behind the fall.

Timber support may be as good as new in dry climates, although dry rot is possible (fig. 27). Damp workings lead to timber rot which may be total or surficial. A good check of timber is to push a screwdriver blade into the wood across the grain (fig. 28A, B). The wood is rotten if you can insert the blade. The point of a geologist's hammer is a convenient substitute (fig. 29). Totally saturated 12 in. timbers, obviously weighing a few hundred

Figure 25.--Unusually severe spalling off the rib caused by slaking. This crosscut in altered limestone is about half filled with water after spring snow melt.

Figure 26.--A large backfall from a cross fault.

Figure 27.--Dry rot is not uncommon but is not always visually obvious as it is here.

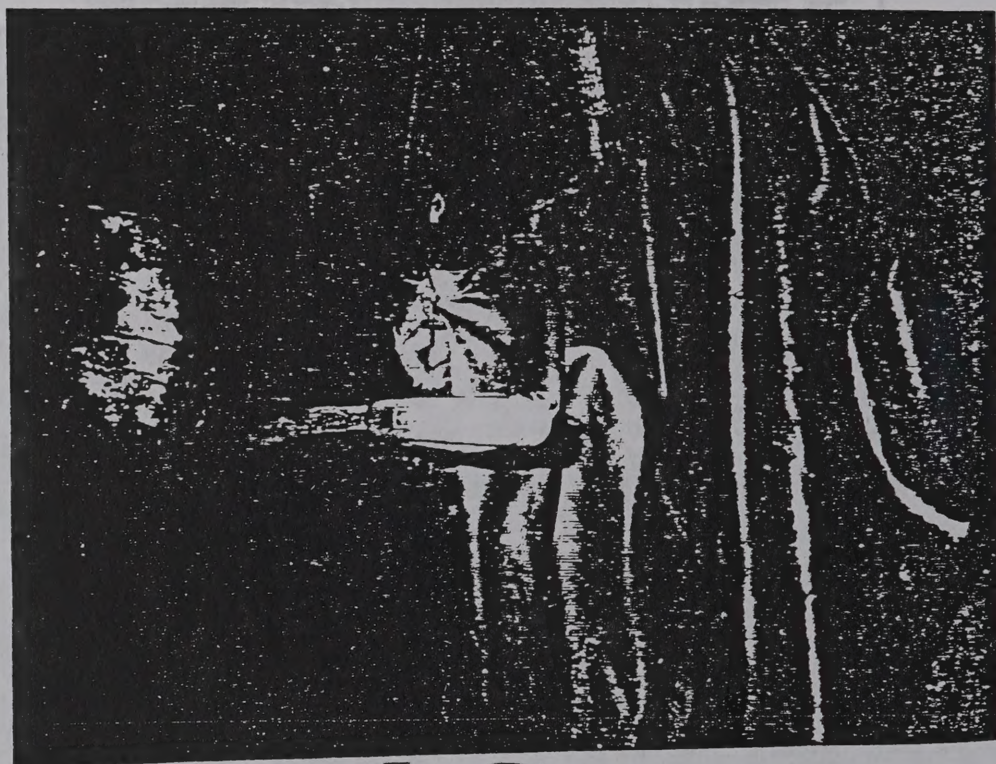


Figure 28A.—When a knife or screwdriver blade can be easily pushed into the wood across the grain the wood is rotten.

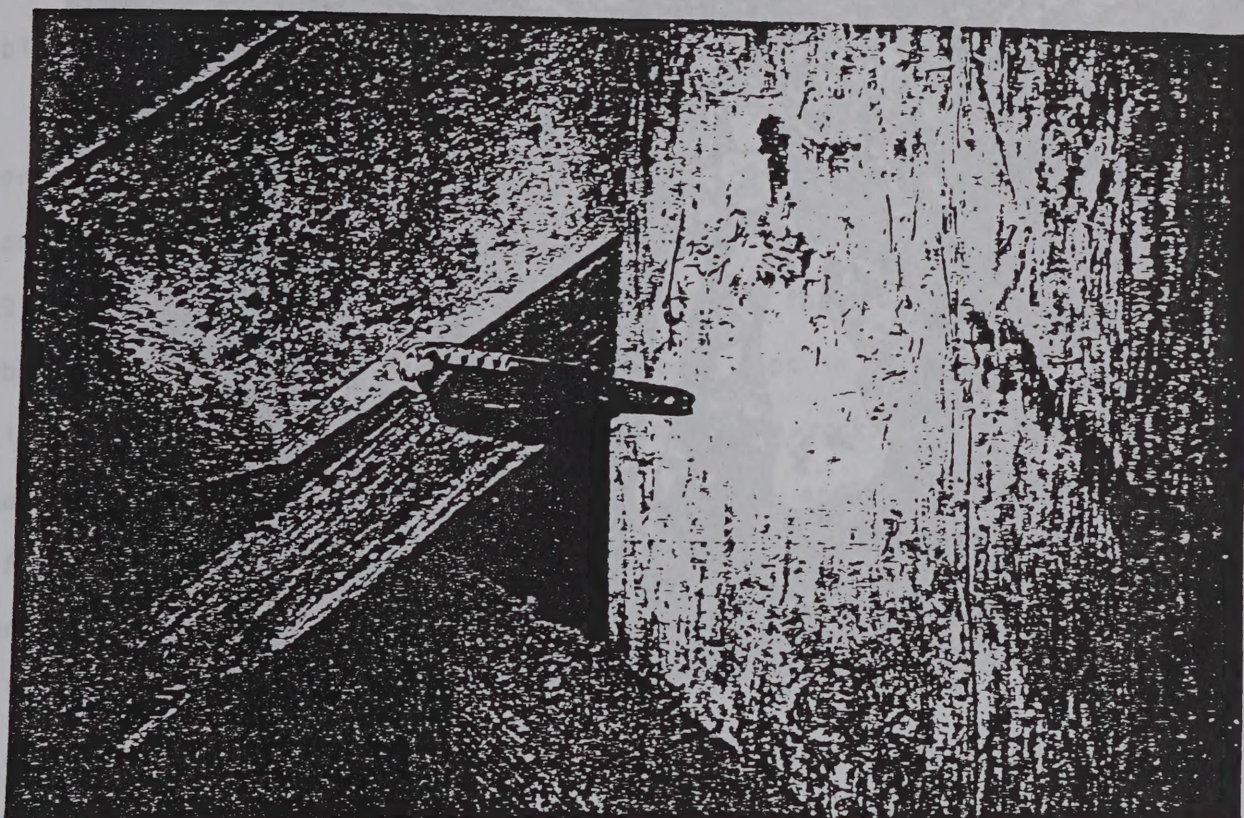


Figure 28B.--The same effort barely gave penetration with the grain of the wood in this sound timber.

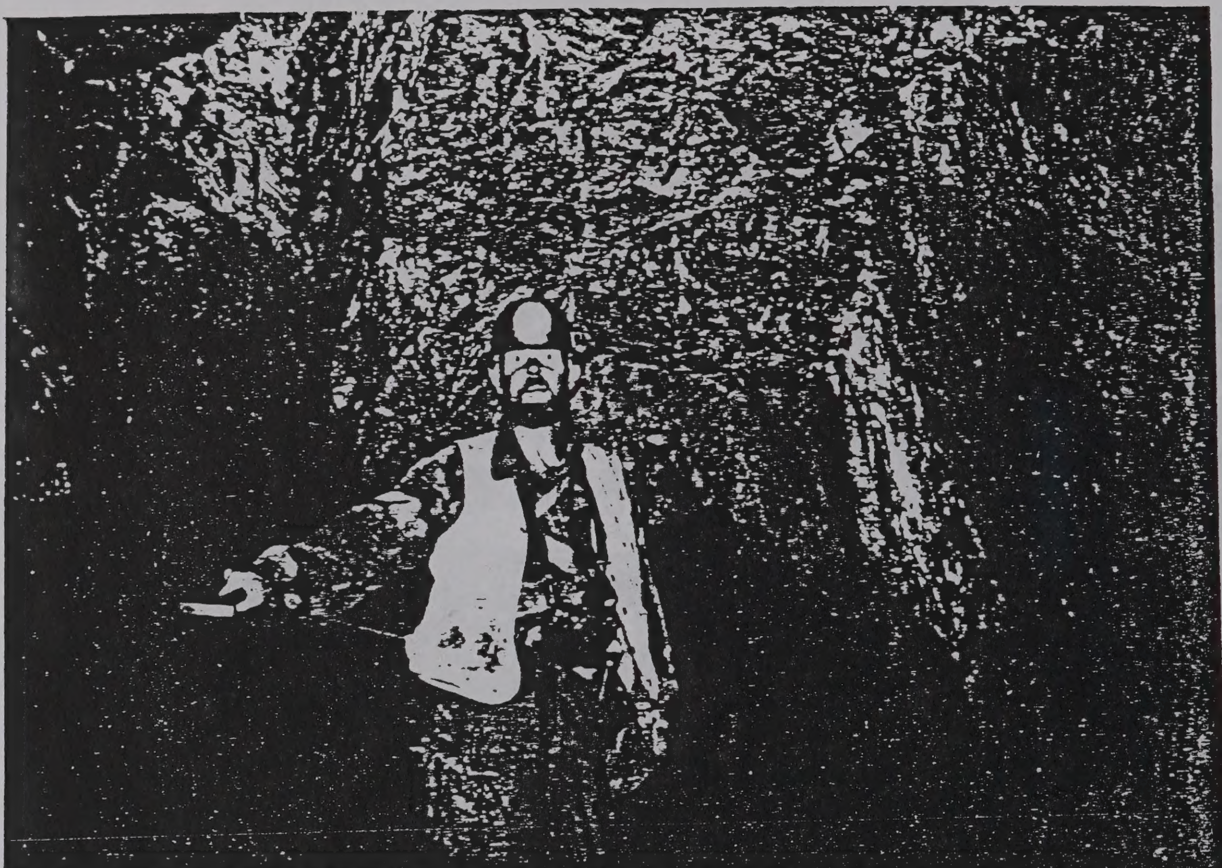


Figure 29.--For convenience the point of a rock hammer can be pushed(not driven) into the wood. Here it has penetrated rotton wood over an inch. Note that the test was made in a safe place in contrast to the place shown in figure 8.

pounds have been observed, supported by timber so rotten you could push all four fingers into it (fig. 30) or tear off large chunks (fig. 31). There had to be a fairly sound core inside the rotten timber to support that load. Timbered areas should be assumed to be a geologically weak zone, and one that cannot be evaluated. It is probable that the timber, even where partly rotted, is supporting some loose rock (fig. 8), but it should not be assumed it can support any additional load. Sound timber, on the other hand, may be able to support any additional rock you could possibly knock down.

Procedures.--If you find an area of unfailed timber, the most experienced person should examine the entire area alone. This person should check the soundness of timbers, preferably while not under the timbered section (fig. 29). This way he can avoid pushing down a timber that supports rock or timber above his head. He should try to see through gaps in lagging or above cross timbers at the ends of the area to evaluate the rock. He should look for bowed, buckled, or crooked timber (figs. 27, 32), and caps that may be loose (fig. 33). Avoid touching any unsound or dubious timber while under it because it could dislodge one or more chunks of the timber (fig. 34, 35).

Where a fall has occurred, but the working is not blocked (fig. 26), you can cautiously climb up the pile and inspect the failed area. Unless water is running from the rock at the time it is probably temporarily stabilized. Sampling is probably ill advised, but you can pass the fall safely enough if you can avoid brushing the back, which could dislodge a new fall.

Areas of blasting-caused weakness

Blasting causes fractures (overbreak) that extend into all sides of a passage. These and pre-existing fractures create a locally weak part of the

18.

Figure 30.--An extreme case of rot.

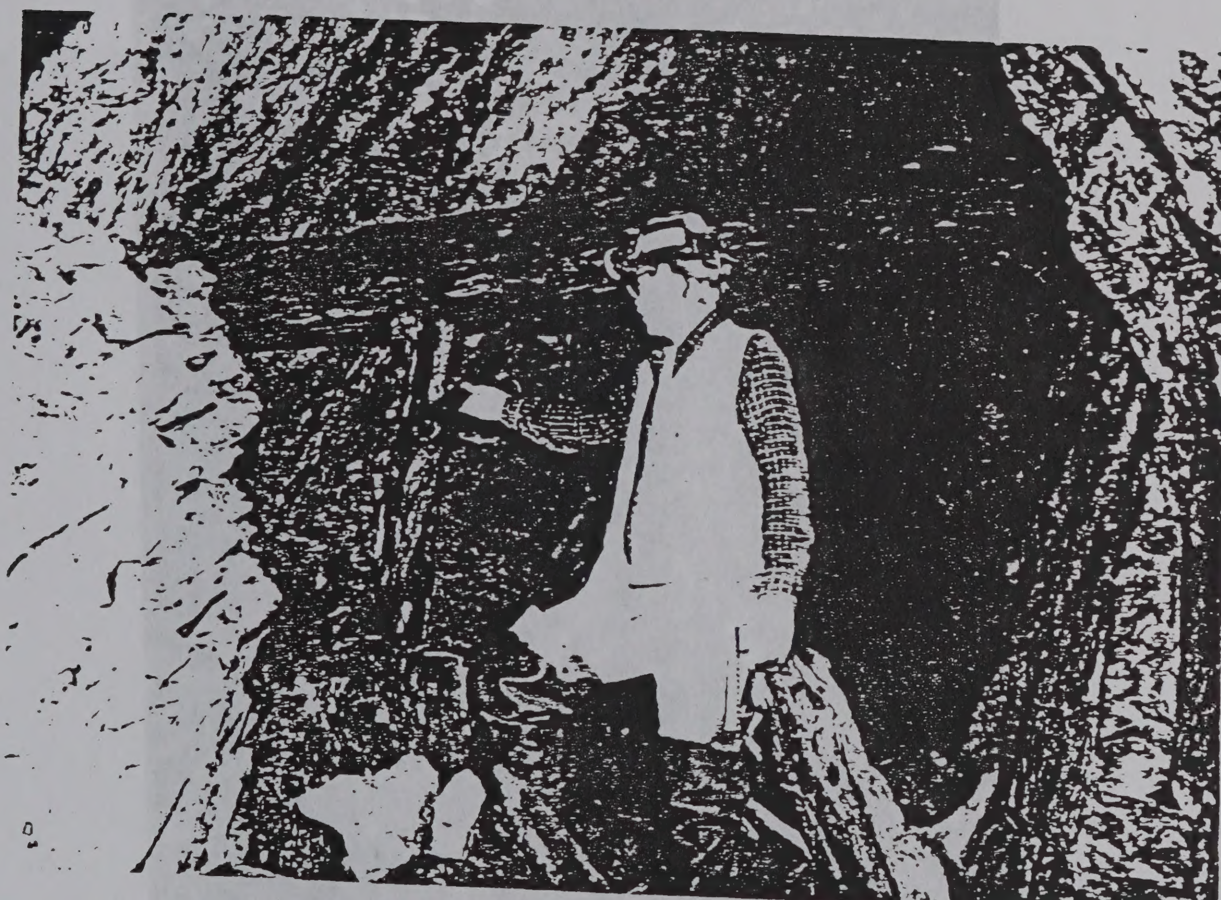


Figure 31.--This post is so rotten that slabs can be torn off by hand, but the core is sound enough to support a massive, water-logged beam. The tester is a little too close to the beam for comfort if it should fall other than straight down.

5.

Figure 32.--Timbers in various states of failure. They appear to be yielding to pressure above ~~a yielding to pressure above~~ and on the right,but it is difficult to believe they can withstand any pressure in this condition.

Figure 33.--A sound post with cap and wedge firmly in place. When wood dries it can shrink and leave the wedges loose, in which case the timber can easily fall.

Figure 34.—If you feel you must be in a place like this do not touch the timbers. Failed timbers can fall on you along with loose rock. A timber falling out of place could let more dirt and rock flow in and possibly block the opening. The entire area could collapse.

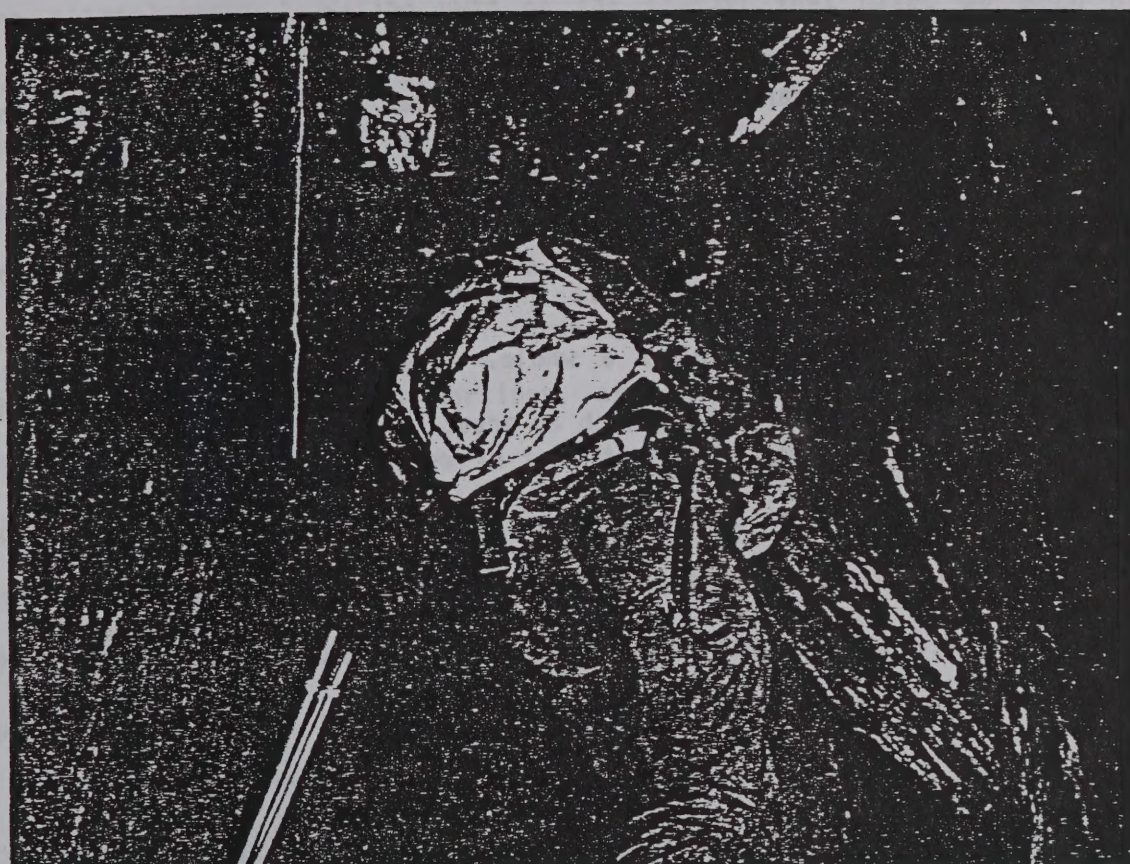


Figure 35.--Passing through failed and failing timbers, if ever attempted, must be done without disturbing anything. Here a camera tripod (or pipe, drill, etc.) is used as a support while easing through an awkward opening.

rock mass. Blasting and barring down by the miner will knock down the loosest blocks early in the mine's life. The rest of the fractured rock will become less coherant from natural causes, mostly groundwater movement. Individual blocks or clusters of blocks can fall with or without disturbance.

Evaluation

A high density of randomly oriented irregular fractures can be a sign of using too much explosives. It may be localized or found everywhere in the mine. The irregularity of the fractures results in some interlocking of fragments, but if the rock mass has prominent pre-existing fractures the interlocking mass may dislodge as a whole. Try to disloge loose fragments with a long bar before going under such an area.

Procedures

If prodding with a bar does not dislodge much rock it should be safe to map in a highly fractured area, but sampling is ill advised. It's better to take samples from rocks on the sill.

Explosives

Partial boxes of dynamite, or a scattering of several sticks of dynamite, are found rather often in inactive mines. Blasting caps are probably present as often, but being much smaller, may not be noticed. Unfired dynamite has been found in holes in the last working face and in the muck pile from the last blast.

Dynamite will deteriorate rapidly if improperly stored, and often deteriorated explosives are more hazardous than those in good condition (E.I. DuPont, 1969, p. 969-970). Such material should only be handled by an explosives expert.

Evaluation

With few exceptions, only an explosives expert can determine the condition of explosives. If sticks of dynamite have beads looking like beads of water, they are definitely subject to detonation from jarring. These beads are nitroglycerin "sweating out" of the sawdust that makes up much of the dynamite stick (fig. 36A, B). Dynamite which is little more than waxed paper and a little sawdust has generally lost all its nitroglycerin and is inert. In all other cases you don't know how great the hazard is, so you must assume it is extreme. The more explosive the greater the hazard. Dynamite may be found as scattered sticks or in cardboard or wooden boxes. Modern boxes are cardboard, and other than markings, are not obviously dynamite boxes. A closed box presents a problem in that it may be empty, contain dynamite, or contain something harmless. If you don't want to look you'd better assume it's dynamite. If you do look, leave the box open so someone else won't have the same problem. Old dynamite boxes were wooden, and usually tongue and groove construction, so they are easier to identify.

If the last round blasted at the working face was not mucked out there can be unfired sticks in the muck pile, so look for them when approaching the face. Where drill holes are in the face or back, look into them. There could be unfired sticks left after blasting, or holes could have been loaded and not shot.

Procedures

Standard disposal of explosives is by burning, which gives off fumes that are toxic (E.I. DuPont, 1969, p. 80) and must be removed by forced ventilation. The only recourse when explosives are found is to walk away and don't disturb them. If the quantity is small, a few caps or a stick or two,

Figure 36A.--A cardboard box of dynamite. Nitroglycerin is starting to sweat out.

Figure 36B.--Close view of the beads of nitroglycerin on the of surfaces the dynamite sticks.

and located in some side working well away from your exit route, you might just avoid that part of the mine. If mapping the mine, a pace and compass sketch map should be made as you walk out so that you have no reason to even consider going back.

The proximity you may feel is safe will depend not only on the quantity of explosives, but the soundness of the rock and timbering. In general, the banging and jarring you could cause in your work will not be detectable a few hundred feet away.

Should an explosion occur, but cause no immediate harm except severe fright, you must leave until the fumes from the explosion have gone, as they are toxic. In an unventilated part of a mine this could take weeks.

The best way to cope with explosives is to go quietly away and stay away, however, haste in departure will increase the chance of explosion. Just walk quietly out, drawing a map as you go.

Falls

Falls are a possible hazard in inactive mines with more than one level. Open shafts and winzes are obvious hazards which are generally treated with due respect, but covered, and sometimes hidden openings can exist. Apparently stable ladders, timbers, or rock piles can prove otherwise.

It was not uncommon practice to board over a winze or the lower level(s) of a shaft once ore was believed to be depleted in that direction. If other parts of the mine remained active rail might be laid on the boards, and after a few months the boards could be hidden under loose rock making the sill appear indentical to the sill on solid rock (fig. 37A, B). Wet or dry rot can eventually weaken the boards to the point of collapse.

Figure 37A.--The sill in the foreground felt slightly different, calling attention to the pipe. The pipe obviously goes to a lower level, and obviously goes through a winze.

Figure 37B.--The same pipe about 3 ft lower. A few soggy boards and timbers are holding up the broken rock hiding the top of the winze.

In some cases raises or stopes were driven upward almost into other stopes or drifts. Only a foot or so of rock--fractured by blasting--may remain. Old time miners and prospectors were more likely to "follow their nose than their head", and do things not found in text books.

Evaluation

Shaft collars with obvious caving that forms a crater around the shaft collar can only be approached safely on a rope, because the edge of the crater can crumble or slide beneath you. There is almost never a reason to go farther than the edge of the crater, and virtually no reason to approach in the first place. Shafts with intact collars can appear safe to examine at close hand. Before doing so, evaluate the collar. If it is in soil, great caution is advised, because collapse can occur in the soil around the collar. Next look at the timbers (if any). Are they just a cover for the hole or are they shaft timbers? The former would be unsupported if the side of the shaft sluffed away, but shaft timbers, being wedged into the shaft, could remain in place if the wedges are still tight, a condition that cannot be checked without centering the shaft. If the timber ends are on solid rock you might get close enough to check the timbers for soundness. Only if everything seems sound do you get close enough to look down the shaft.

Ladders should be considered unsafe for use even if sound and stable at the top because timbers farther down may be loose or rotten and nails could be rusted away. It is common to have the top tens or hundreds of feet sound, only to reach a damper area nearer the water table where resultant rust and rot have weakened the ladder. When descending a ladder about all that can be seen is whether rungs are present and the nearest ladder end attached (fig. 38). You can't evaluate soundness of the ladder below except by feel. If a

Figure 38.—The man on the ladder cannot visually inspect the rungs below as he descends. You shouldn't climb a ladder in this condition, but you can evaluate it easily without endagering yourself. If descending, you can't make that same evaluation from a safe place.

rung gives way under one foot the resultant weight shift could cause another rung to fail setting up a chain reaction leading to a fall. It is rare that a vertical or near vertical shaft can be descended with any resemblence of safety.

Hidden holes, such as winzes, can best be anticipated and expected if you understand what the miners were doing so you can anticipate why and where these holes may be hidden. Some workings are beyond logical description and were probably the work of a demented mind, but most follow a recognizable logic.

Large, multi-level mines used winzes/raises for ventilation, but in older, smaller mines winzes were generally only used to follow the ore. Winzes can be expected on, or adjacent to, a geologic structure that was being mined or prospected. They are not to be expected in a cross-cut unless it intersects a structure.

When topography allowed, it was common to drive an adit for drainage and haulage below the active working levels. Often the haulage levels cross cut to the structure. Observe the pattern of dumps on the hill. Dumps that are aligned are probably from adits driven on the same structure. Even though the various levels may not be connected you should assume that this process was begun, and expect winzes. If there is a very large dump lowest down it is probably a haulage level connected to one or more upper levels. When underground try to determine if you are on a haulage or upper level, because the upper levels will have winzes and/or ore chutes going down. Haulage levels are generally higher, wider, and straighter than the norm for a given district. Rails, or the ties for rails, may remain, but rail may not have been used, or left in place, in upper levels. Ore chutes may have their lower

ends visible, and manways and other raises will be present. Winzes on haulage levels are not common, and if present are generally sunk to one side of the heavy traffic.

Boarded-over winzes can often be located even when loose rock covers the boards. Unless the winze was very shallow a windlass was generally set up to raise broken rock. This generally required a widening of the drift. That, remains of timbers not used for back support, and remains of the windlass or other hoisting apparatus, can indicate the winze location before you put weight on the boards (fig. 39, 66, 70). An ore bucket of any kind on an adit dump should be interpreted as indication of a winze somewhere inside until proven differently. In some cases windlass cranks were parallel with the drift and there was no widening of the drift. There may be pieces of board showing through the rocks, you may feel a slight give when you step on the boards, or your steps may sound a little different. Any of these indicators calls for investigation of the cause before proceeding.

Winzes are more commonly open or partly boarded over than completely hidden. Boards, pipe, or rail may be the only bridge across if the winze occupies full width of the drift. Any of these, especially boards, should extend at least a foot onto solid sill on each side of the winze if you would consider using them as a bridge. Boards should be at least 2 x 10 in. (3 in. is required minimum in current practice) and sound; pipe should be at least 4 in., no more than slightly rusted, and preferably laid along a rib. Rail should be at least 1 1/2 in. across and, like pipe, near enough the rib that the rib can be used for balance (fig. 40-42); and the winze should be shallow enough or inclined flatly enough that you could survive a fall if you intend to cross. Pipe or rail must not be able to rotate underfoot and spill you

17.

Figure 39.--A sheave wheel is used in hoisting. This is evidence of a winze even if none is visible.

Figure 40.--Proper technique if you must walk, a board, pipe, or rail across a winze. A hand on each rib keeps you from slipping off the pipe or losing your balance. The board in the foreground would be a better choice if it is sound and long enough.

to high

Figure 41.--Proper technique where the size of the opening is unknown. Bracing the hands on both sides lessens the weight on the feet.

THIS PAGE LEFT INTENTIONALLY BLANK

off. If the mine is at all damp your bridge will probably be slippery, so having the rib for balance is desirable even if the bridge is a plank.

Obvious boarded over winzes, and landings in winzes and shafts, can always be given the rock test. Toss a rock, at least softball size, onto various parts of the structure and see if anything moves or breaks. A less certain indicator is the sound of the rock hitting. A sound, dry board will make a sharp bang. A dull thud is a signal for extreme caution. A dull squish is clear evidence of a wet, rotten timber or board with no strength.

Procedures

If there is any opening below the level you are on, there is a way to fall into it. Visible holes can be easily avoided by remaining several feet away. If you are on a planked area you should assume it is over a hole, otherwise they wouldn't have wasted lumber.

Climbing ladders up shafts or raises, or into stopes is far safer than descending ladders. Going up you can visually inspect each rung, the nails, the wood, the way each ladder segment is held in place, and its bottom attachment, and inspect, by feel, the parts before you put weight on them. Few people have as good a sense of feel through boot soles as with their hands. The feet should be placed next to the uprights, not in the middle of the rung, so there is less chance of breaking a weak rung. Rungs inset into the wood will hold weight even with no nails, unless you pull out on them. At least one hand should be behind the upright, and grasp it, so you can't peel off backward if a rung pulls off (fig. 43A, B). I once climbed a ladder up a raise where the third and last section was nailed to the middle section with four nails. Wood and nails were in fine shape. The last section was

Figure 43A.--Correct ladder technique. If a rung fails the climber will not fall backward, but simply take all weight on the other foot.

Figure 43B.—Incorrect ladder technique. Pulling back with the hands can pull off a rung and the climber might then fall off backward.

essentially vertical. Assuming it was attached at the top I climbed it. It wasn't; it was wired to a 4 x 4 post which was now lying loose on the sill. Had I been leaning back I probably would have ripped the top ladder off the one below and fallen. It is desirable to climb a ladder with your movements smooth and your weight in close to the ladder because it minimizes the chance of breaking something. I retreated as gently as I went up, and now shake ladders much harder before trusting a higher section. Even this is hazardous as you can bring loose rock or ladder pieces down on your head (fig. 44). Where ladders are missing or unusable, aluminum extension ladders can be brought in, or a ladder can be built for access (fig. 45A, B).

Steeply inclined stopes present several possible problems. Manways and ore chutes may be hidden by loose rock with no visual clues as to location. Rock tossing at any depressions or other suspicious areas may give warning before weight is put on them.

Some stopes are flat enough to collect broken rock at the angle of repose (about 35°). You may be able to walk across these or you may dislodge the loose rocks and fall with them. If parts of the loose rock shift when you toss a big rock on it, it is marginally stable and will probably slide. If the hanging wall is in reach and you can push against it, keeping your weight more nearly perpendicular to the footwall than vertical, you can probably cross a marginally stable slope (fig. 46).

Stopes too steep to collect loose rock may be climbable if the footwall is not too smooth. This requires rock climbing skills (fig. 47) as well as skill at dealing with clayey, slickenslided surfaces (often wet and slippery) or dust and sand on all the holds.

Figure 44.--Many ladders are not firmly fastened in place. Check to see if they can slip, tip, or fall before using, but be careful not to pull one down on your head.

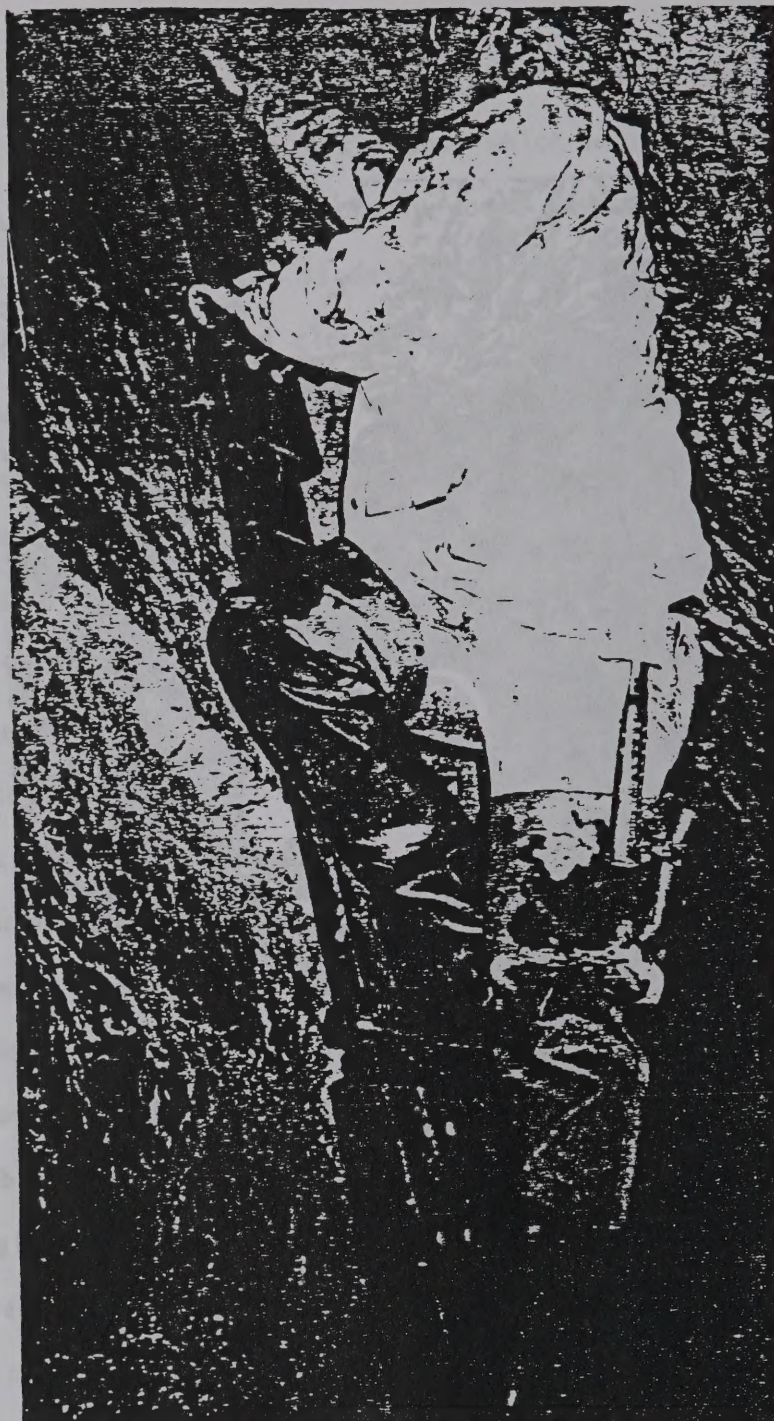
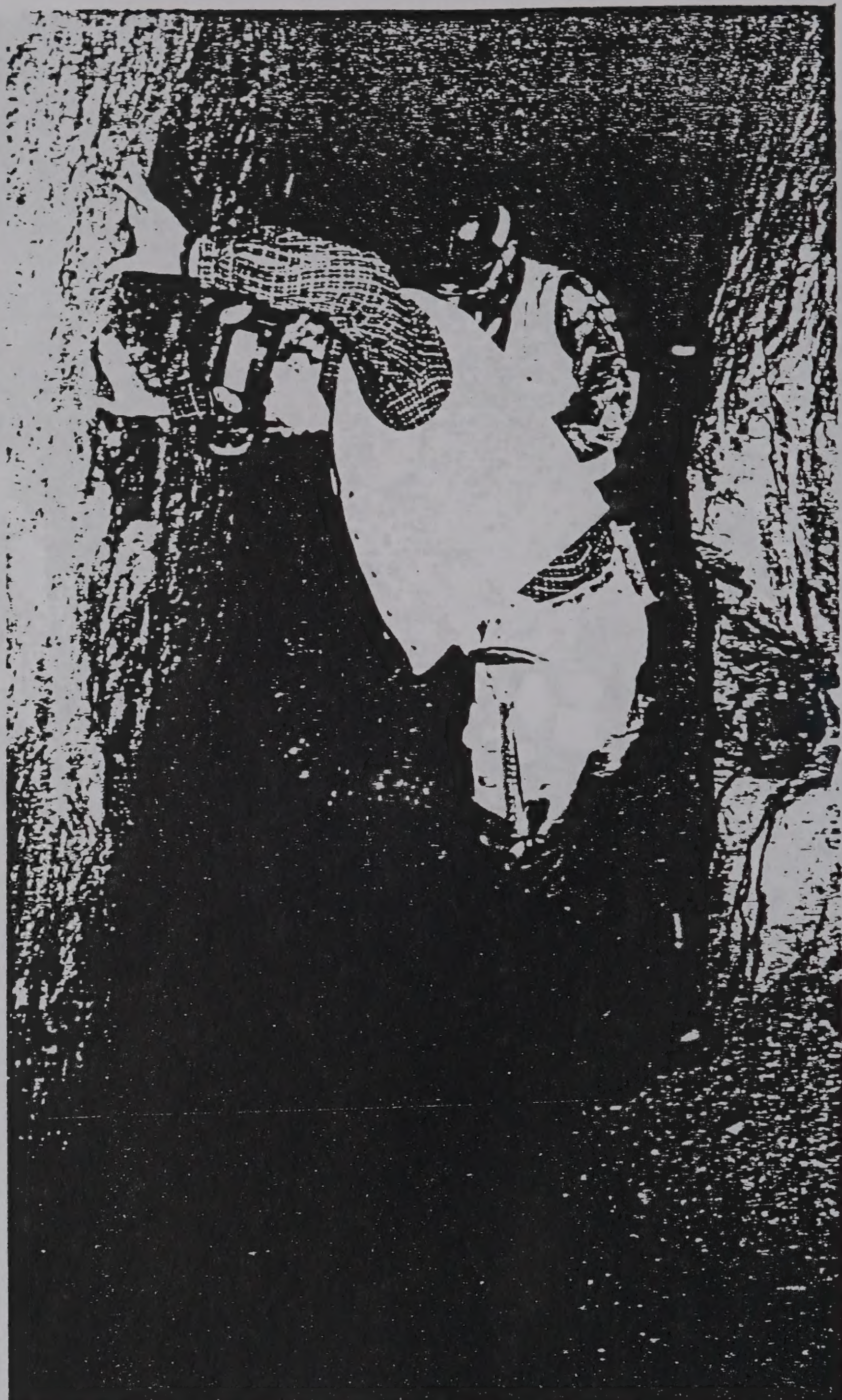


Figure 45A.--This ladder was built in three sections, carried 5 mi, and bolted together in the mine. This provided access to another level of the mine. Note placement of the right foot to maximize contact with the rung.

Figure 45B.—The top of the ladder. The man has his hands on the ribs of the raise to prevent the ladder from tipping.



16.

Figure 46.--Correct technique for walking a narrow, gravelly ledge, or the footwall of a steeply inclined stope. Pressing the hands on the opposite rib (or hanging wall) prevents slipping off.

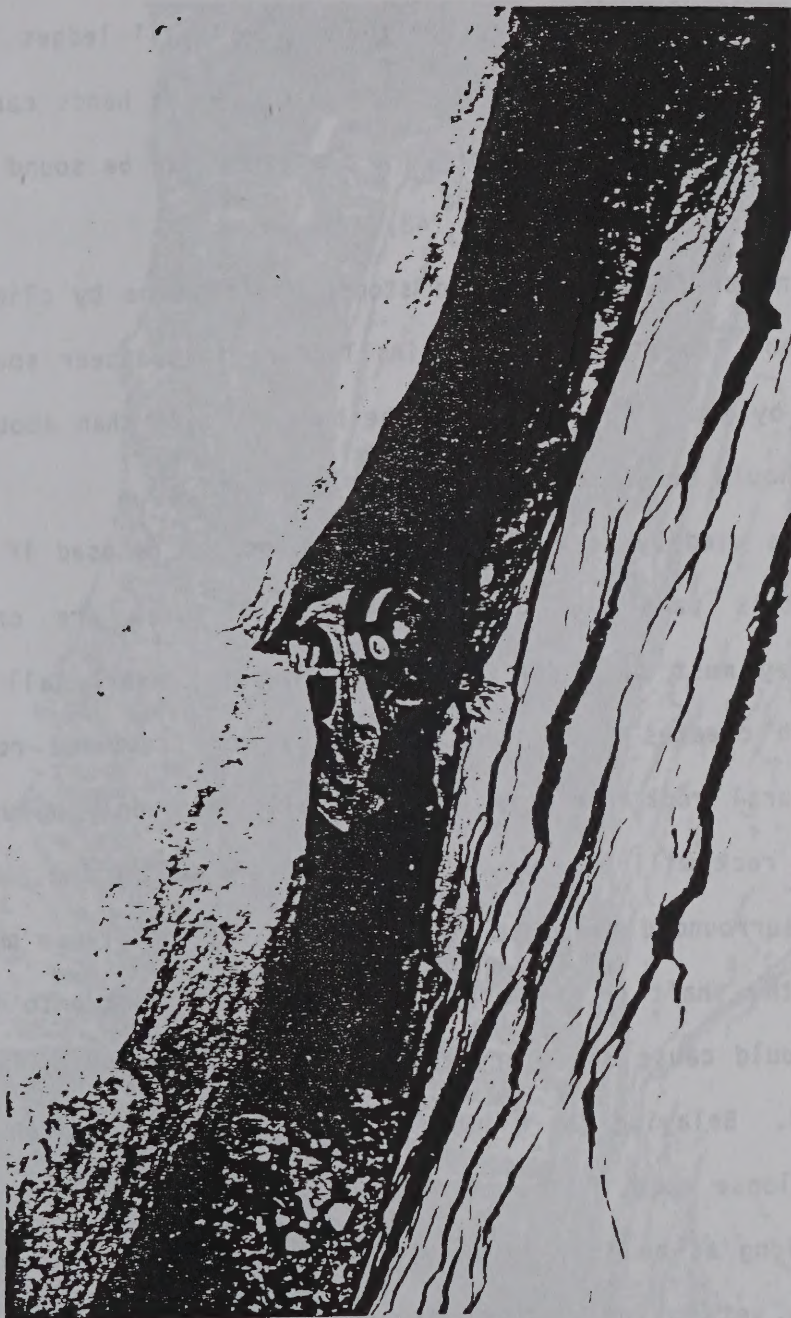


Figure 47.--Climbing up or down stopes may be possible even though ladders are absent, but knowledge and experience with rock-climbing techniques is necessary.

Stopes may be open along a drift and have small ledges leading across. Crossing is more hazardous than climbing because the hands cannot be used to as good an advantage. Remains of work platforms may be sound enough to use, but must be checked carefully (fig. 48).

Descending shafts, winzes, and stopes may be done by climbing (fig. 47) if they are not too steep, or by using ladders that appear sound (fig. 43A), or are built by you (fig. 45B). If the hole is more than about 10 ft deep a safety rope should be used with the ladder.

Techniques used by rock climbers and cavers can be used if you are expert with them (this paragraph and the following three are only for those experts). They must be modified because in mines nearly all openings were blasted, which creates a few to several feet of fractured rock around the opening. Natural rock surfaces will generally have only natural fractures, and the loose rock will be removed by erosion and weathering, whereas blasted openings are surrounded by loose rock. Rappelling will cause movement of the rope against the shaft or winze collar and dislodge rock onto the rappeller. Direct hits could cause an injury that would cause him to loose his grip and fall unchecked. Belaying the climber or rappeler requires even more movement of rope over loose rock. Its only advantage is that the climber won't fall free, but as long as he is hanging on the rope the belayer can't move unless he is properly set up for that possibility. The preferred method is for the climber to tie in about 3 ft from the end of the rope. The free end of the rope is tied onto the rope above the climber with a prussik knot (the knot must never be out of reach). Excess rope is dumped down the shaft or winze and the climber belays himself. The rope above hardly moves and he could only fall a few feet if hit by a rock or the ladder breaks. His partner has a

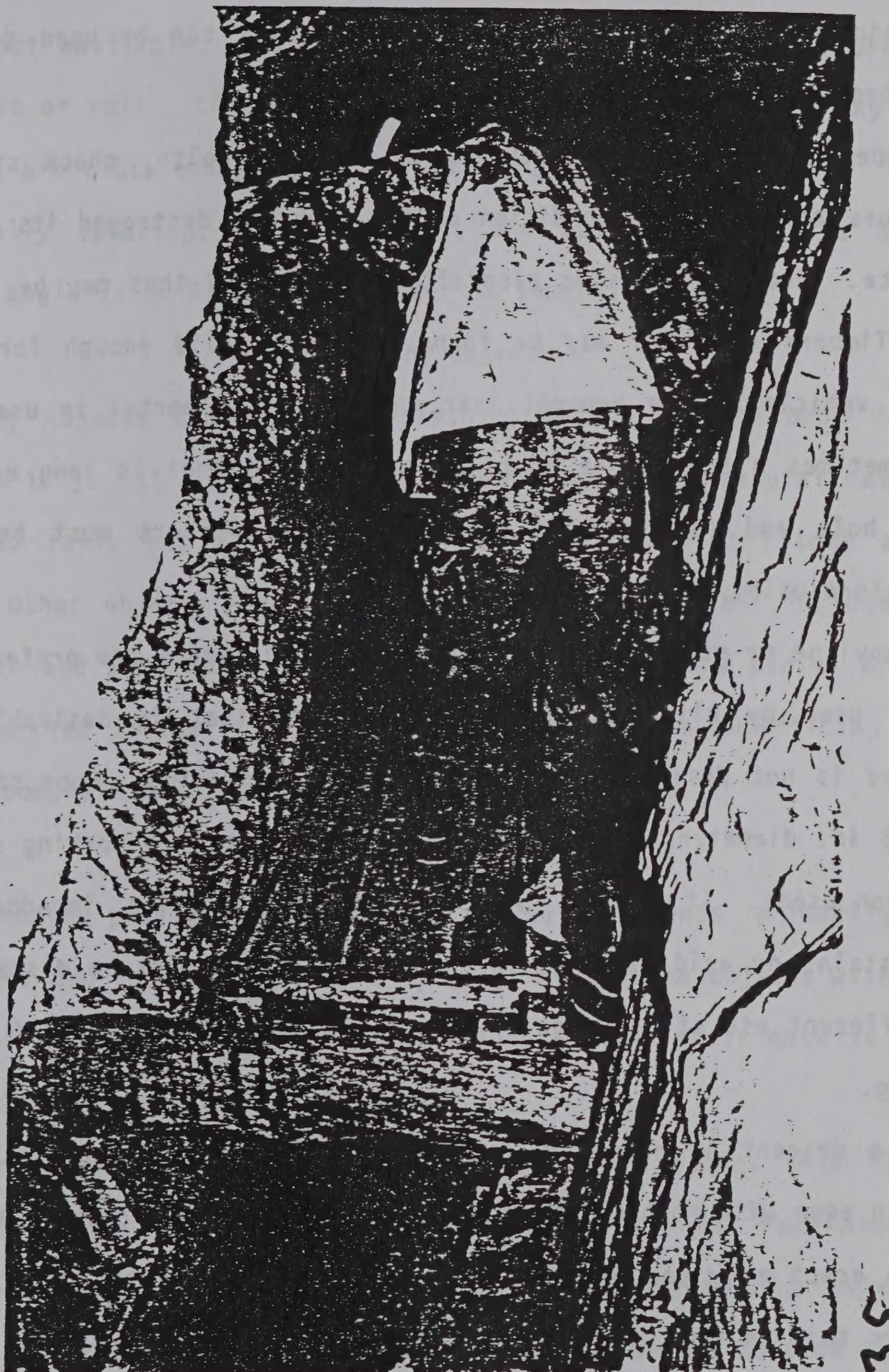


Figure 48.--Work platforms may remain in place and provide access in stopes. Wood must be sound and the stulls firmly wedged.

chance to aid him if he is injured. Nails and wire can be used to repair occasional bad rungs as he descends.

The rope cannot often be anchored to rock by bolts, chock stones or pitons because the fractured condition of the rock has destroyed its strength and coherance. Rock in mines is also often altered and thus may be severely weakened. Timbers or pipes may be found that are solid enough for use as anchors. A vehicle may be brought near enough to the portal to use for an anchor. Sometimes a stout tree or pole can be found that is long enough to bridge the hole and can be used for an anchor. Anchors must be tested carefully before using.

Polypropylene or other low-stretch ropes used by cavers are preferable to nylon ropes used by climbers because the stretch that is desirable in a climbing rope is not desirable for caving or mine exploring. Rope should be at least 3/8 in. diameter and at least 2,000 lb test (800 lb working strength new--less when used). It must be inspected for cuts, abrasion, imbedded rock, burns, oil stain, or acid damage before each use. Rope must be discarded or put to a different use at any sign of damage. A bowline knot should be used for anchoring.

Should a descent be necessary for rescue purpose the ropes must be run over a smooth edge with nothing loose available to be knocked down. It may be necessary to erect a tripod or windlass-type structure over the hole and run the rope over this so that the rope does not run over the edge of the hole at all to accomplish this.

Extension ladders can be a good bridge for crossing winzes and thus open up additional parts of a mine for exploration. Adequate bridges may be built if enough sound planks are available. Tight-rope walking pipe and rail is

generally not advisable. Either can turn and dump you if not secured so they cannot twist or roll. If secured and not weakened by rust, they may be usable if the ribs are close enough to aid balancing (fig. 40).

Generally speaking, winzes, shafts, and open stopes should be avoided unless the angle is so flat that a ladder is superfluous.

Falling objects

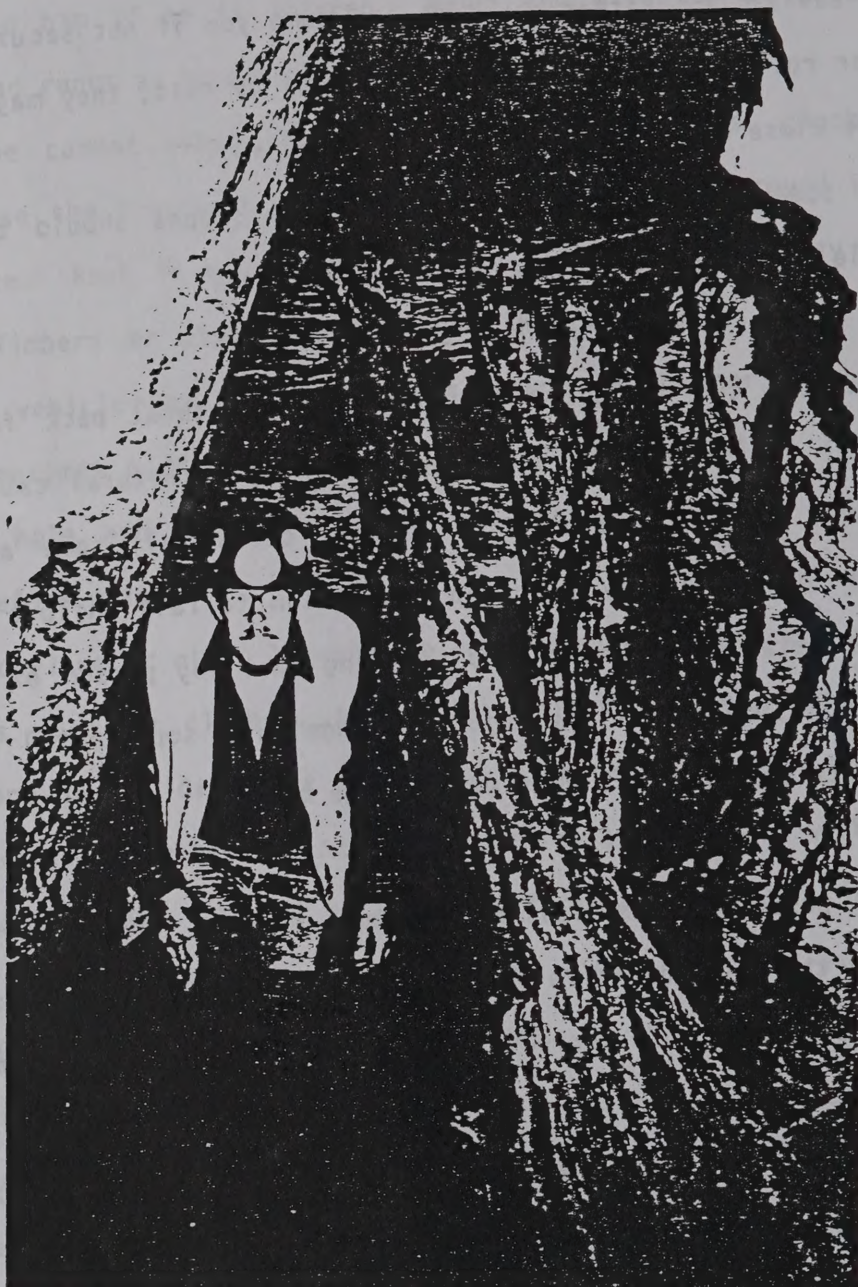
Falling objects can include everything except natural back fall (rock fall, "cave-in"). It includes rock broken by mining or natural causes which has come to rest, but because of its location could fall some additional distance. Other objects likely to be in a position to fall include timbers, ladders, air and water pipe, tools, and anything that any person or creature may have carried inside. Possible injuries range from superficial cuts and bruises to complete crushing of all or part of the body.

Space

Evaluation

The damage possible from falling objects depends primarily on the object's mass and the distance it falls (fig. 49). Some objects with sharp or pointed configuration may cause serious injury even if their mass is small and their fall distance short.

In a simple, one-level mine with no raises or stopes this hazard is confined to objects which don't have far to fall. Except for large timbers and sections of pipe, there is not much that can cause serious injury. Rot, wet or dry (fig. 27, 30), often attacks timbers and wedges so that they are no longer held firmly in place. Most timbers have sufficient mass to cause serious injury if one tips over on you (fig. 29). Your hard hat and hard-toed boots offer adequate protection for what they cover. Even so, a long section of pipe (fig. 50) can do serious injury if brought down on yourself. Dry



20

Figure 49.--These_rotten timbers don't have far to fall, but_are large enough to cause injury if they do.

Figure 50.--Heavy pipe hung by wire attached to wooden wedges. Rot and rust can leave the pipe vitually unsupported, but where it is along the rib it's unlikely it could fall on you.

mines may have sound pipe, but pipe in damp mines is very likely to be well rusted. Ventilation, water, and compressed air pipes may be found on the sill (fig. 40), back, or ribs (fig. 50). Hangers are often no more than wire and large nails. They may be nearly rusted through in places, and break and fall from little disturbance. Ventilation pipe is generally large-diameter sheet metal (in old workings, but fabric is common in modern usage) and more likely to inflict cuts from jagged edges than to cause a crushing injury. Water and compressed air use heavy pipe which can cause more severe damage. Such pipe, if along the back where you can get under it, should be checked for soundness, as well as soundness of the pipe hangers.

Where a mine has winzes, stopes, or levels above your position, the objects that fall from them can pick up enough speed to cause serious injury regardless of the mass of the object.

Raises may dead end in plain view, curve out of sight, or reach another level. They may have a timbered landing, with either a complete cover or with an opening for a ladder. The condition of landings and amount of rubble on them can't be evaluated unless the ladder is usable (see section on falls). Even if the mine is bone dry it is best to assume that the timber is rotten and barely supporting itself, and avoid spending time under the raise (fig. 51). Dead end raises with no timbering present no unique threats in the falling object category. Raises to the surface frequently get soil and rock washed in by rain or knocked in by animals and people. A large mound of debris below the opening is a clear indicator that a hazard is present before you are close enough to look up and see the sky. These raises should be avoided during heavy rains, or if people or animals frequent the area around the collar. People enjoy dropping things down holes.

Figure 51.--A raise with wet, and probably rotten timber and ladders is an area to avoid.

Manways can be merely a raise with a ladder, or a completely timbered opening with regularly close-spaced landings. When the mine is in use they are generally kept tidy and in repair, but debri accumulates (fig. 52), timbers rot, and nails rust through. You may be faced with a shakey mess or access to another level. Ladders should be checked for security of rungs, attachment top and bottom, condition of the nails in the rungs, and soundness of the wood before you attempt any climb. If the ladder seems sound, the landings above may be. If the ladder or any other timber in the mine is rotten (fig. 53) you should assume all the timber above is, and stay off. No one else should be in a manway when someone is climbing. At each landing some rocks will probably be brushed off or kicked down. In very dry mines the timber will probably be sound, however the supports for landings are held in place by wooden wedges. As timber and wedges dry they can shrink and barely stay in place by friction (fig. 48) until some additional weight is placed on them causing them to fall.

Ore chutes are used to funnel broken ore from stopes into ore cars. The lower end is usually an inclined wooden trough constructed so that the flow of ore can be regulated by means of some sort of gate--often just a heavy board. If the gate still exists, it is likely that there is some quantity of loose rock behind it (fig. 54). This loose rock may be held by the boards or by a chock stone some where above. Poking around in the bottom of an ore chute is not unlike peering down the muzzle of a cannon to see if it's loaded (fig. 55).

In some mines the stopes are open directly to the haulage level. Work platforms (fig. 48, 56), loose rock, timbers (fig. 57-59), or other objects, can fall or slide out of the stope, and the disturbance can cause a chain

Figure 52.--Almost anything may have been left at landings, ready to fall at some provocation.

Figure 53.--Heavy fungus growth (showing white on this ore chute) generally indicates wet, rotten wood. Dry timber can be equally rotton (fig. 27).

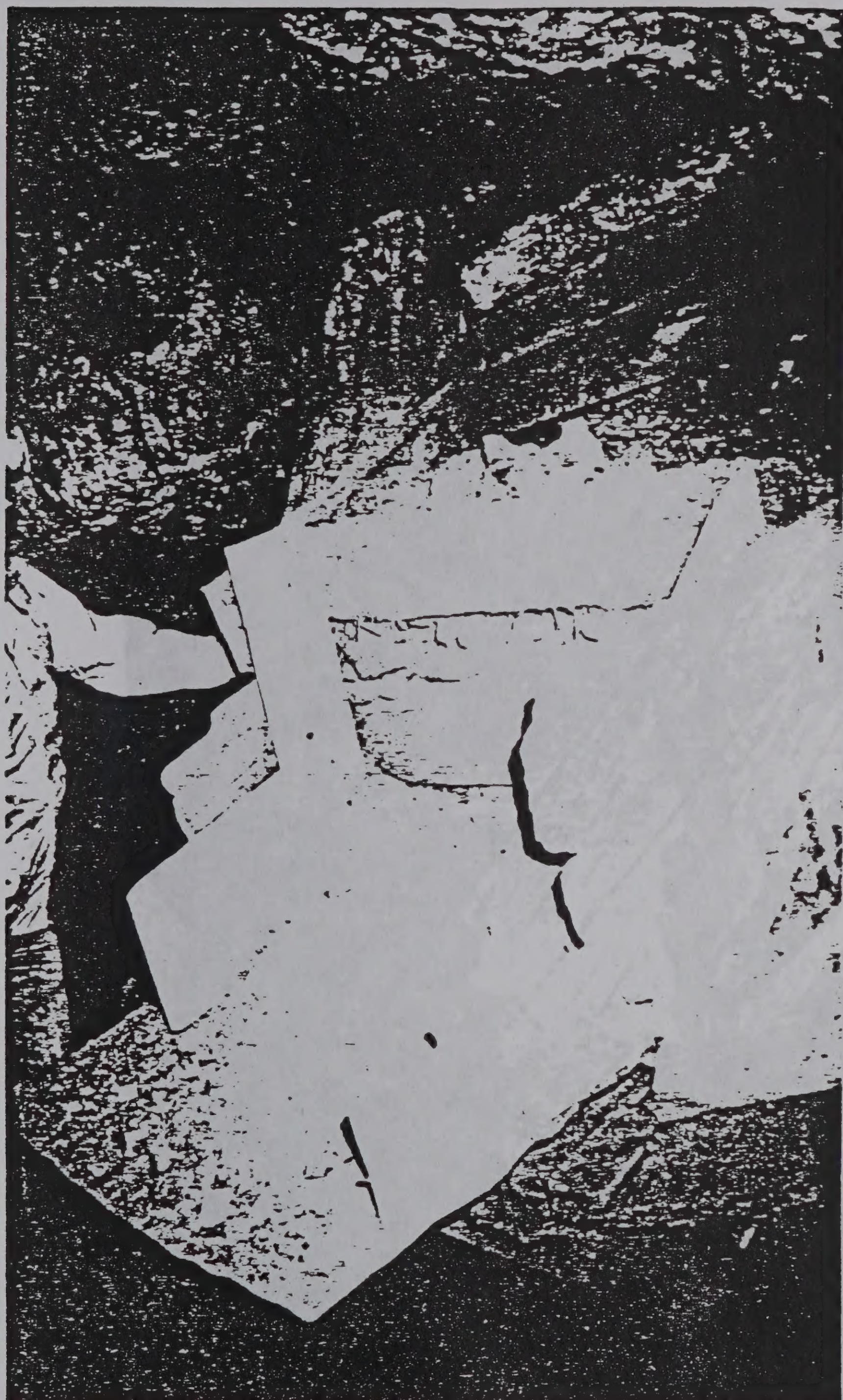


Figure 54.--An ore chute filled with rock. Failure of the gate boards will dump this rock, and possibly much more, into the haulage level.

Figure 55.--Generally the rock comes down but the chute doesn't. All rules have exceptions.

Figure 56.--The heavy timbers of this work platform can fall if disturbed. They probably support some amount of broken rock as well.

37.

Figure 57.--The timbers above look sound, but are not obviously supported. Develop the habit of looking up.

24.

Figure 58.--These large and rotten timbers can pick up enough speed to cause serious injury if they fall.

reaction fall tens of feet away. Ore chutes are small danger points, whereas open stopes are larger danger areas.

Procedures

Any time work is done on more than one level all workers involved must know where the other is at all times. It is nearly impossible to avoid kicking some loose rock down (fig. 59), so it is imperative that no one below is in the fall line when the person above is moving.

Any pipes or timbers present should be tested from a safe place before you go under or place weight on them, and time spent under them should be as brief as possible. A post, pipe or rail from the dump, or a sturdy tree limb is useful to prod these objects while you stand safely to one side. Ladders and ore chutes can be treated similarly. The force used in testing an object should slightly exceed that which you might place on it in the course of doing your job. The object is not to knock something down, but to insure that it will not accidentally come down because of your activities. Landings and timbers in stopes are generally out of reach, and must be judged by appearance and the condition of timber you can test (fig. 29). If you decide to go beneath these, move gently and minimize the time spent in the danger zone. In very rare instances sound, empty ore chutes can be used for access to a stope.

When approaching an opening leading up, observe the amount and type of rubble in the pile below it. This will give you a clue as to what could still be up there. It also indicates where not to be when you look up to evaluate the remaining hazard.

Gases

Gases that can be encountered underground may be toxic, flammable, or asphyxiating. They may be naturally occurring or, in active mines, caused by

Figure 59.--The man climbing will kick down some rock. This rock may be supporting the rock perched on the timbers, thus a very large rock and debris fall can result. Do not get in the line of fall of a man climbing.

mining processes. Instruments have been developed to test for hazardous gases because most are not otherwise detectable.

In active mines toxic gases, carbon monoxide and nitrous oxides, are generated by blasting, diesel engines, electrical discharge. Carbon monoxide is also generated by fires. Naturally occurring gases--CO_2, H_2S, CH_4(methane), N_2, NO, CO, and SO_2 can be found in active and inactive mines. Oxidation of sulfides will deplete the oxygen (O_2) content leaving only N_2 and/or CO_2.

Carbon dioxide

Carbon dioxide (CO_2) is colorless, odorless, and tasteless. It is heavier than air and sinks to low parts of mines. In higher concentrations it may displace oxygen and be an asphyxiant. High CO_2 concentrations (as much as 75%) have been reported in the East Tintic district, Utah McElroy, 1921), Cripple Creek, Colorado, and Butte, Montana (Denny and others, 1930). Carbon dioxide concentrations occur when oxygen is depleted by oxidation of sulfides and magnetite, and the sulfur combines with ground water creating a weak acid that reacts with carbonate rocks to generate CO_2. Oxidation of timbers can also produce CO_2 (Denny and others, 1930).

Carbon dioxide responds to barometric changes by flowing out of the rock when pressure is low, in when pressure is high. It is a heavy gas and will accumulate in winzes, underhand stopes and behind back falls. The latter situation presents the main hazard in inactive mines because most people will walk over a back fall and give it no thought while they would hesitate to climb down a winze or stope. The back fall acts as a dam, pooling any heavy gases as it would water. A person walking through these gases will stir them

up, and they can displace enough oxygen to cause that person to black out. That person then will fall and suffocate. Descending into a CO_2-filled winze could cause instantaneous black-out and fall if the CO_2 level is high and the CO_2 is stratified so that the change to a CO_2 atmosphere occurs in a few inches. This can be averted by reading an O_2 meter held at about waist level. A gradual increase in CO_2 content should be detectable without a meter because it causes an increase in the respiration rate, however many people aren't that observant. In all cases the O_2 meter should be used well below head level to give warning in time regardless of the circumstance.

Low concentrations, such as might be found in a CO_2 producing mine with no "dams", or in a low place in a mine that generates only a little CO_2, can be detected by an alert person at levels that are not harmful. An increase in respiration rate should be noticeable at 0.5% CO_2. Respiration rate is twice normal at 3% CO_2 and 10% CO_2 usually proves fatal after a few minutes.

Carbon dioxide can be detected with an air pump and stain tube (fig. 60A, B) or assumed by low readings on an O_2 detector.

Hydrogen sulfide

Hydrogen sulfide (H_2S) is colorless, heavier than air, toxic, and smells like rotten eggs at low concentrations. At higher concentrations the sense of smell is immediately deadened, and generally death follows rapidly. H_2S can form from groundwater and sulfides. If you get a whiff of some odor that might be H_2S you should test for H_2S with a stain tube before entering mine. If underground, go back to fresh air and begin testing there, working deeper underground, checking often. If H_2S is confirmed, get out and stay out.

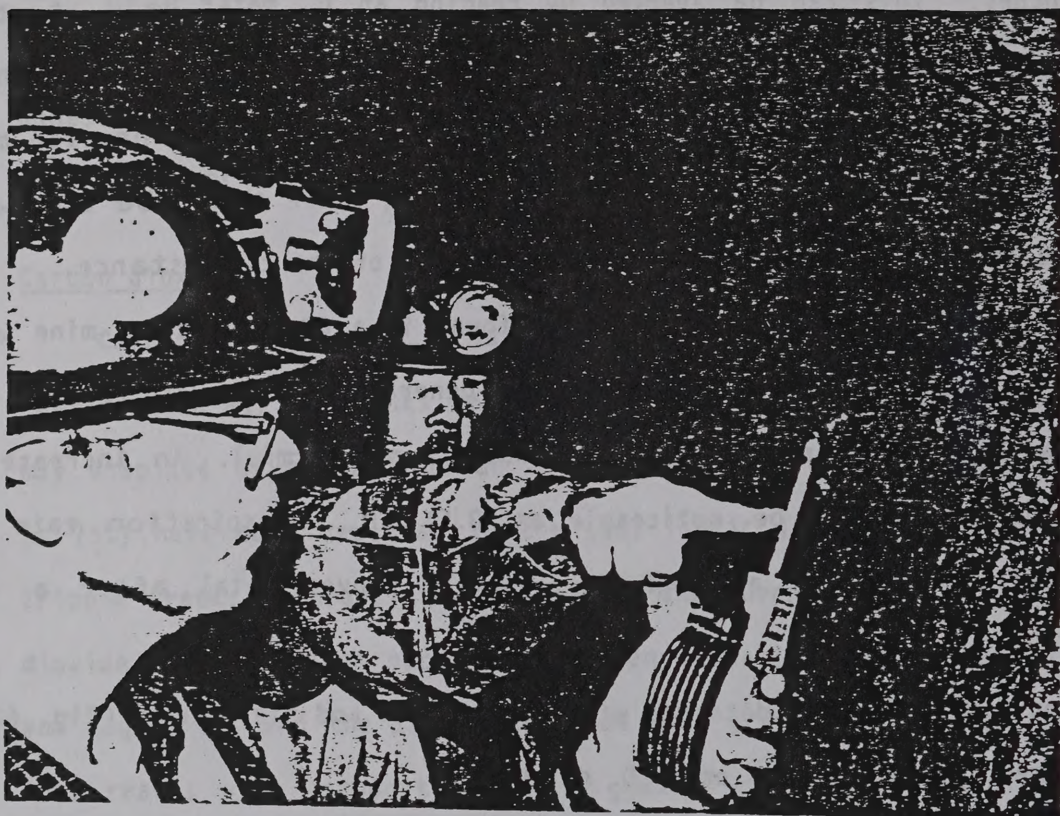


Figure 60A.--A hand pump and stain tubes specific for CO, CO_2, H_2S, NO, NO_2, or SO_2 will detect concentrations of toxic gases quite rapidly.

19.

Figure 60B.--The stain tube reads about 0.08%. In this case the test is for CO_2; this is not a hazardous CO_2 concentration.

Methane

Methane (CH_4) is colorless, odorless, tasteless, highly flammable, and lighter than air. It is common in coal mines and oil shale mines. It is not uncommon in salt and trona mines, and has also been found in some California gold mines (Gardner, 1922). Methane can be expected in any mine in carbonaceous rocks. It presents two hazards; it is easily ignited in concentrations of 5 to 15% in air, causing, in effect, an explosion. In higher concentrations it is an asphyxiant because it dilutes the oxygen (Zabetakis, 1974).

Methane, being light, accumulates in high places in the mine--along the back for example. It can be detected by use of a flame safety lamp or a CH_4 detector (fig. 61). Reading a flame safety lamp correctly requires some experience, so the CH_4 detector is recommended for anyone not completely familiar and proficient with the flame safety lamp. Concentrations of >1% methane should be avoided. Because CH_4 is an asphyxiant you can monitor O_2 if you must enter a suspected CH_4-rich atmosphere but do not have a CH_4 detector, however you must leave at any change of O_2 near 1% because CH_4 could be displacing N_2 as well as O_2. You could thus enter a flammable atmosphere before an asphyxiating atmosphere.

Nitrogen

Nitrogen (N_2) is the major component of the air we breath (about 79%), but at elevated concentrations it replaces O_2 and is an asphyxiant. It is slightly lighter than air. High N_2 content of air in raises killed a number of miners in Nevada (Gardner, 1922). High N_2 content (as much as 98%) was also known at Cripple Creek, Colorado, and in California mercury mines (Denny and others, 1930). We have detected 84% N_2 about 600 ft from the portal of

Figure 61.--An oxygen-methane detector in use. In this instance the oxygen level was only 17% because of nitrogen inflow with the water flow from an open watercourse.

a 2,500 ft haulage level of the Augusta Mine in the Ruby district in Colorado. The N_2 was present in high concentrations because the O_2 was depleted by oxidation of sulfides.

Sudden N_2 inflows have resulted while drilling (Gardner, 1922), but in general, N_2 inflow is related to barometric pressure. When pressure begins to drop, either because of storm systems or diurnal variations, N_2 flows from the rocks. The flow is greater from highly fractured rocks or open water courses (fig. 61). When pressure begins to rise the N_2 will flow into the rocks, but unless they are very fractured and open it will not flow back as rapidly as it flowed out and thus it can build up to dangerous levels (Denny and others, 1930).

Nitrogen, being light, will generally accumulate in raises and stopes. An O_2 detector should be used to see if enough O_2 is present. If this is OK the N_2 itself is no problem.

Nitrogen oxides and carbon monoxide

Nitrogen exides (NO and NO_2) and carbon monoxide (CO) are common in operating mines, but unlikely in inactive mines. Nitrogen oxides are toxic and irritating. If your nose is indecisive and H_2S and SO_2 stain tube tests are negative, test for NO + NO_2 (a single stain tube is used for the combined oxides). Carbon monoxide is odorless, colorless and toxic. If there is any indication of recent blasting or any type of combustion, including a campfire underground, use a stain tube to test for CO. The first symptom of exposure to CO is headache. If one member of a crew gets a headache underground a CO test should be made. If both get a headache it is mandatory to leave and test from fresh air on back in. Symptons of CO poisoning have

been experienced by Bureau personnel in a long-abandoned uranium mine. The incident followed a few days of rain, and it is possible the resulting ground water generated CO while passing through thin coaly beds overlying the working.

Sulfur dioxide

Sulfur dioxide (SO_2) is a colorless toxic gas with an irritating sulfur odor. It is easy to detect and difficult to tolerate. The natural reaction--to avoid it--is the correct one. It can form from sulfide ores, but is not common in inactive mines.

If your nose is giving you signals that are not clear you should test for SO_2 with a stain tube as you also test for H_2S.

Oxygen deficiency

Normal oxygen content of air is 20.9% O_2. When the O_2 content drops below 19.5% the air is considered O_2 deficient even though many people can work when O_2 content is as low as 17%. In a mine, lack of O_2 is generally because of an increase of N_2, CO_2 or both. Any place in a mine where there is no flow of air can be O_2 deficient for reasons discussed under N_2 and CO_2, or because while working there your respiration decreases the O_2 and increases the CO_2.

When you are out of fresh air flow you should use an O_2 detector and leave it on as you work. A 2% decrease in O_2 content has been observed after working about 10 minutes in a small stope. An audible alarm is desirable on the detector so you will be alerted in cases such as this.

Oxygen detectors are generally affected by altitude, and should be calibrated to 21% at the portal. Altitude compensation may introduce an error, so to err in favor of safety you should leave if the O_2 content drops below 18%.

In an O_2 deficient atmosphere the mind does not function properly. Although you can live in 16% O_2 you may not recognize any symptoms of danger and remain in the O_2 deficient atmosphere or continue into a more deficientatmosphere until you black out. People react differently to O_2 deficiency, and a given person may not always react in the same way. Some people seem to have a sixth sense, and can determine safe air without testing devices. In truth those people are listening to what their body tells them and taking the advice it gives on those particular occasions. A person's desire to get a job done may cause them to ignore warning signals. A bad cold can confuse warnings of SO_2, H_2S, NO_2, and NO. Some people are so attuned to the chemical odors of cities they do not react to them, but react to the unfamiliar odor of stale bat guano. Some people just never listen to their body. Even the rare individual who can "always" detect bad air should use appropriate test equipment so their partners are ingrained with safe habits. Three of our people were able to detect a 2% O_2 decrease in an O_2 defficient mine, but their symptoms were not the same and the symptoms could have been attributed to other logical causes.

Procedures

You cope with bad air by avoiding it. You avoid it by beginning appropriate tests when warning odors are encountered or when you get out of fresh, moving air. You continue to test as you reconnoiter the mine. You test all stopes, winzes, and raises with no air flow; you test beyond all back falls. After reconnaissance you continue to monitor O_2 content so that O_2 consumption or N_2 or CO_2 inflow from barometric pressure changes does not catch you unaware. Even though inflows of N_2 and/or CO_2 result from

oxidation of sulfides or magnetite, and CO_2 generation generally requires carbonate rocks, you cannot assume they are present or absent by observing wall rocks or dump material. Wall rocks at East Tintic are quartzite, in Cripple Creek and the Nevada district rocks are assorted volcanic breccias and silicified rhyolite. In Augusta Basin in the Elk Range, Colorado are the Augusta Mine haulage adit and the Yankee Blade prospect adit. Both have had bad air reported. Both adits are in hornfels.The Augusta dump shows abundant sulfides which came from the Augusta vein, 2,500 ft underground. The Yankee Blade dump has no sulfides. Near its end it cuts an open water course that probably connects with a sulfide vein explored on the other side of the mountain. At the watercourse (1,240 ft from the portal) the Yankee Blade has lost 4% O_2 (fig. 61). The loss is no greater at 1,420 ft at the face. The Augusta lost 5.4% O_2 at about 700 ft. In both the O_2 was replaced by N_2.

Before descending the far side of a back fall first toss a few rocks to see if water is backed up behind it. Proceed down, feet first, using your oxygen meter below head level. CO_2 a heavy gas, can be ponded behind the fall. Walking through the gas, even if it is below the level of your head, will stir it up; waves of CO_2 will displace oxygen, causing you to pass out. Once you fall into CO_2 you will die of asphyxiation. If your O_2 meter shows 1% or so decrease past the fall you should use the hand pump and stain tube to determine if CO_2 is present near the sill. If so, you must proceed very slowly to not stir up the gas, if you proceed at all. If CO_2 does not account for the O_2 drop, it is likely that excess N_2 is present because of poor natural ventilation. In this case your movement will cause no adverse mixing effect because N_2 is only slightly lighter than O_2, and

will be already mixed. With either CO_2 or N_2 you must monitor the O_2 level constantly in order to not go beyond a safe level.

Large mines can most safely be worked in the morning in fair weather. Diurnal pressure highs are at about 10 a.m. and 10 p.m. Fair weather generally correlates with high barometric pressure. If rapid changes in CO_2 and/or N_2 concentration with change in barometric pressure is possible in a large mine the O_2 concentration could become dangerously low just in the time required to walk out. Don't work your way into a mine, work your way out.

Use of breathing apparatus to enter mines is not advised. Such equipment is used for rescue during and after mine fires and to recover bodies. The self rescuer is intended to get you out of a mine if there is a fire. It is not to get you into a mine that may have CO. Unless you plan something stupid like starting a fire underground, it has no use in inactive mines. The only appropriate way to enter a mine that has bad air is to ventilate the mine. If you can't do that, stay out.

Radiation

Radiation hazards are of two types. The obvious hazard is gamma rays given off by uranium minerals. Alpha and beta radiation levels are hazardous only in extremely unusual conditions (Rock and Beckman, 1979, p. 6). The other hazard is from radon daughter products resulting from the decay of radioactive minerals.

Gamma radiation can reach hazardous levels in uranium mines. Continued work in uranium mines should dictate use of a dosimeter so that exposure can be monitored and limited to safe levels. A dose of 5 REM (equal to 2.5 mR/hr per 40 hr wk) in a 12 month period is the legal safe limit for gamma radiation (Rock and Beckman, 1979, p. 7).

High readings on a scintillometer or gamma ray spectrometer in the absence of other test equipment could indicate that your exposure should be kept brief.

Radon gas

Radon gas is a decay product of uranium and other radioactive minerals. Radon gas presents a serious internal alpha radiation hazard to the lungs because it can decay to its daughters while in the lungs. The daughters are particles that adhere to the lining of the lung and can deliver considerable alpha energy to the lung in a short time. Epidemiological studies have shown increased incidence of lung cancer among uranium miners exposed to radon daughters. (See Rock and Walker, 1970, p. 6-7.)

Radon levels can also be high in non-uranium mines. In either uranium or non-uranium mines the radon levels are controlled by ventilation. Parts of inactive mines with no natural ventilation can reach high radon concentrations over a number of years.

Very limited tests by this office have shown interesting results:

1. Uranium mine in sandstone, idle 30 years: all samples contained less than 0.001% U_3O_8.
   face, 540 ft from portal, 20.6% O_2, 8 WL
   drift, 270 ft from portal, 20.7% O_2, 6 1/2 WL
   crosscut, 135 ft from portal, 20.9% O_2, 1 1/2 WL

2. Copper prospect in the same formation as above, idle 80 yr:
   face, 380 ft from portal, 20.9% O_2, 1/2 WL

3. Prospect in black shale, idle 50 yr:
   face, 1,420 ft from portal, 16.9% O_2, 1 1/2 WL

4. Haulage tunnel in same formation, idle 50 years:
   7 x 7 adit, 700 ft from portal, 15.5% O_2, 3 WL

5. Iron mine in limestone, idle 50 yr:
   cross cut, 200 ft from moving air, 20.9% O_2, 1/4 WL

6. Gold mine in gneiss, idle 80 years:
   face, 1,460 ft from portal, 20.7% O_2, 4 WL
   drift, 360 ft from portal, 20.9% O_2, 0.04 WL

7. Gold mine in intermediate volcanics, idle 50 yr:
   haulage adit, 700 ft from portal, 19.3% O_2, 8 WL
   400 ft from portal, 4 WL, 100 ft from portal, 0.2 WL

One WL (working level) is defined as any combination of short-lived radon daughters/liter of air, which, in decaying completely, will result in the emission 1.3 x 10^5 million electron volts of alpha energy. An exposure to 1 WL for 1 hr = 1 WLH. 173 WLH = 1 WLM. Safe exposure limits are 4 WLM/yr. (See Rock and Beckman, 1979, p. 7-9.) Eight WLH per day is the maximum exposure considered safe.

Although safe exposure limits have been established for workers who are continually exposed, there is inadequate data to determine the hazard involved in short duration, high level exposure.

Evaluation

Radon daughter concentrations once were measured by filtering 10 liters or more of mine air for exactly 5 minutes. The daughter particles are trapped on the filter paper, and counted on a calibrated instrument 40-90 minutes after sampling (fig. 62A, B). The reading is converted mathematically to working levels. (See Rock and Beckman, 1979, p. 13-14.) Newer equipment in use at IFOC will take and read the sample in 4 minutes, and only requires addition to calculate the working levels.

The equipment needed for radon testing is heavy, bulky, expensive, and needs frequent calibration. It is safe to say that most people would not test every mine they enter. Our limited test results show that oxygen will decrease at a nearly linear rate where there is O_2 deficiency because of excessive nitrogen, and no obstructions to air movement. Radon, however, increases somewhat exponentially as the face is approached. In all cases

Figure 62A.--A battery-operated air pump being used to test for radon daughters. The pump takes an air sample through a special filter in the white holder at the end of the flexible tube. The time the pump runs must be measured accurately.

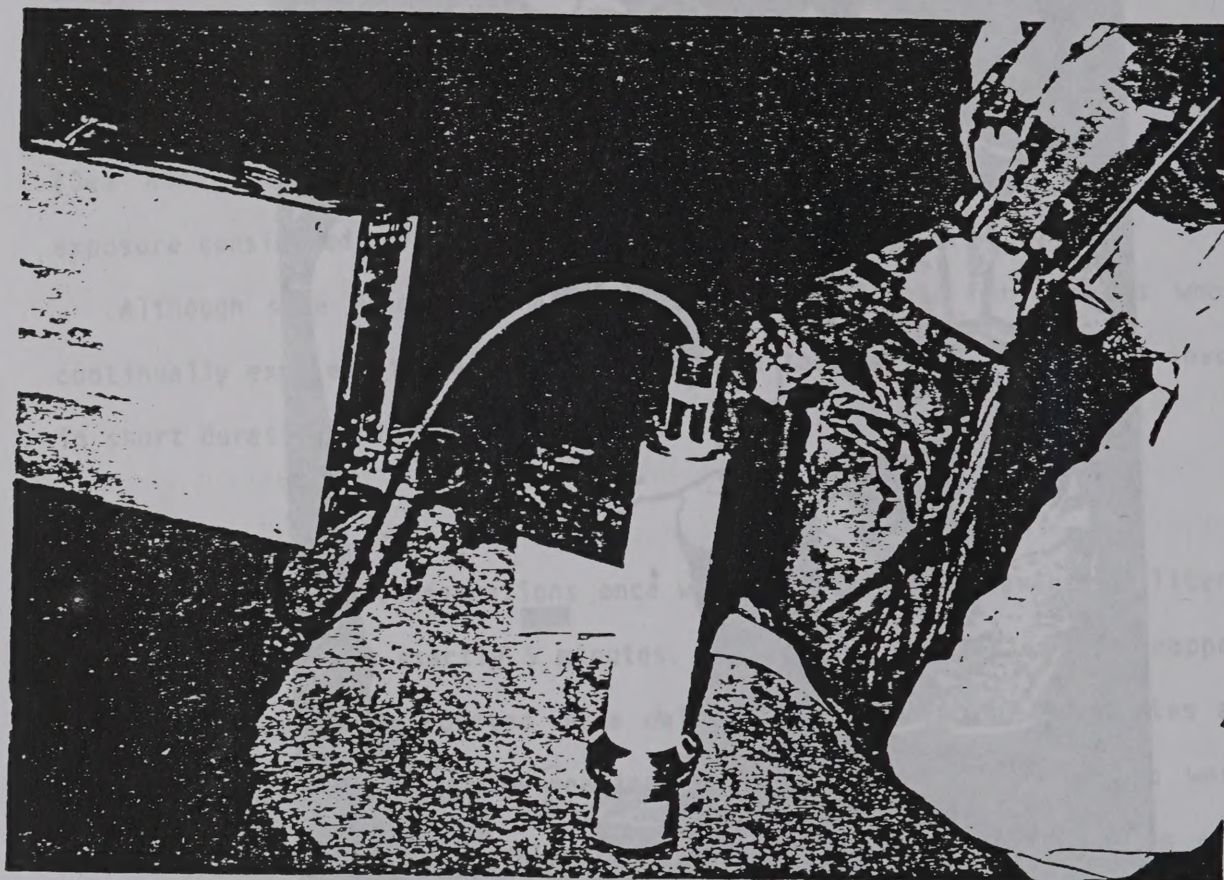


Figure 62B.--The filter is placed in the tube in the center, which is the sensing unit of a scintillometer. The box records counts over a specified time period. This number is mathematically converted to working levels. If time allows, this should be done outside in case radon daughter levels turn out to be high.

where O_2 content was less than 17% there was high radon. Phrased differently; low O_2 generally indicates high radon, but normal O_2 can accompany high or low radon content.

Procedures

It would be prudent to test any uranium mine in which you might spend more than 1 hour. I would recommend not exposing yourself to 8 WL for any time period. This is a personal opinion, and an even more conservative approach should not, in my opinion, be criticized.

Respirators are available that will filter out daughter particles attached to dusts, fumes, and mists. Assuming that radon gas (not filterable) contributes about 5% of the radiation dose attributed to radon daughters, an exposure of 20 WL may be approached while wearing a respirator (20 WL x 5% = 1 WL). Such respirators can be used while measuring radon levels. (See Rock and Walker, 1970, p. 51-53.)

Oxygen content of mine air should be monitored if the mine extends more than a few hundred feet. Areas of the mine with less than 19% O_2 should be tested for radon. Any mine you might spend over an hour in should also be tested.

Water

Water is an indirect hazard. It can hide winzes (fig. 63), rot timbers (fig. 31), rust pipe and rail, and loosen rock and clay in faults and veins. Prolonged working in cold water can bring on hypothermia. Still water can allow a build up of mud that makes for treacherous footing. A fall resulting from such bad footing could result in cuts, bruises, or even drowning.

Figure 63.--There is a water-filled winze in the foreground. The man's hand rests on one leg of a windlass, which is the only clue that a winze is present.

Evaluation

Shallow running water presents the least problems. Even though it may rot timber and rust pipe and rail, it carries away most of the silt and clay, and the sill will be firm and only slightly obscured by mud as you walk (fig. 64). Common 12 or 16 in. muckers are ideal in this situation.

Water ponded behind a back fall or portal sluff can have a surface current if deep enough to flow over the obstruction, but generally some depth of mud will be deposited in the quiet deeper water. Besides the resulting poor footing in the mud, the mud will cloud the water and hide other hazards from view. This situation may require anything from muckers to chest waders (fig. 65).

Deep, still water is nearly certain to cover in deep mud unless the ponding is quite recent.

Most ponds behind portal or back falls will become gradually shallower because adits are generally driven inclined upward a few degrees for drainage. You could need waders at the portal, but be in only an inch or so of water in a few hundred feet farther. I have seen water-filled underhand stopes in a mountain top adit in southern Arizona. The source was rain water from the surface. The fine dust from blasting sealed the rock, and being underground there was no evaporation, so the water became several feet deep over the years. This sort of water supply may attract animals.

I have seen one water-filled winze that had fine dust on the surface of the water. It looked just like a concrete slab until I tossed a rock into it.

...e to SAB - Look at this situation

8.

Figure 64.--Running water on a gravelly sill will not hide any hazards.

Figure 65.--Deep water may require hip or chest waders. The sill usually will be muddy, making footing tricky and clouding the water. In cloudy water the first man must move slowly so he can observe the bottom ahead of the cloud of silt.

Procedures

Shallow water is not a big problem. At worst you may need to go outside and warm your feet once in a while. Deeper water will chill you faster simply because it contacts more of your body.

When the bottom is muddy and you stir up mud that clouds the water you will have no visible warning of subsurface hazards. In this situation use a pipe, pole, drill rod, etc., for a combination probe and walking stick (fig. 66A-B). Probe carefully, then take a step or two and probe again. Once you have checked out the whole mine you won't need to probe, but may still want your walking stick if deep mud makes the footing poor. Try to avoid stepping on ventilation pipe. It will probably collapse under you and could either give you a spill or cut through your muckers if rusted enough to break. If you feel wood, hear a hollow sound or wood underfoot, or feel a little give underfoot that is unlike sinking in the mud, you could be either on loose planks (too water-logged to float) or on a boarded over winze or stope (fig. 66B). If it's not a loose plank you'd better back off and stay off.

Keep your eyes open for wide spots that could indicate a winze, or for remains of windlasses or other hoisting apparatus (fig. 39, 63, 67). If water is near the tops of your muckers or waders they will probably take in water during a long step. It isn't too hard to warm up, even if cool outside, if you just get chilled through the muckers. If you took on water and soaked your clothes it's hard to warm and hypothermia is very possible. Short steps--sort of a shuffle--are best so you can feel for obstructions that can cut your muckers. If mud is really deep you can't shuffle, but short steps give better balance and easier recovery from a slip.

Figure 66A.--Probing deep water in front of you is advisable. This man apparently found something he doesn't like.

21

Figure 66B.--The pipe on the sill is easy to see before any mud is stirred up. Less obvious are the dark areas parallel to the pipe. There is an underhand stope here, crossed by three timbers, the center one of which has the pipe on it. The probe penetrated a timber more than an inch.

Figure 67.--A hoist drum. There should be a winze close by.

Some mines have enough inflow from faults to simulate rain. You need to wear rain suits in these places. Wheat lamps work reliably in these mines, but D-cell head lamps can get wet and quit, so your spare light may get use.

Water flow in mines is related to ground water, but seldom has immediate response to surface precipitation. Some mines could receive direct surface flow from normally dry stream beds or elevated stream flow. In these instances you could be trapped or drowned by rapidly rising water if the mine is so large you can't get out in a few minutes. These mines usually show old "waterlines" or silted in low areas as indicators of higher water levels.

Ice may partly plug a wet mine during winter and remain long after spring thaw. If there is space to walk or crawl on the ice you need to test the ice often. Farther underground the temperature gradually warms and the solid ice at the portal can slowly change to a thin layer over water a few hundred feet in. You could get a surprise bath in ice water if you aren't careful.

Some mines have "heavy" ground that heaves, swells, or flows when saturated, but may be fairly stable when the water table is lower and the ground dry. This ground can swell and flow in a hurry with little disturbance blocking passageways in a few minutes. In appearance it may resemble coarse sand to clay, but will have left a pile where it moved from rib or back into the mine opening (fig. 68). If it is no more than damp, treat it very cautiously. When it is wet avoid it.

Getting lost

The majority of inactive mines present no opportunity to get lost underground. I have seen only three that it was possible to get lost in. All are large, multi-level mines following replacement deposits in limestone. In character they resembled a cross between a mine and a natural cave. A room

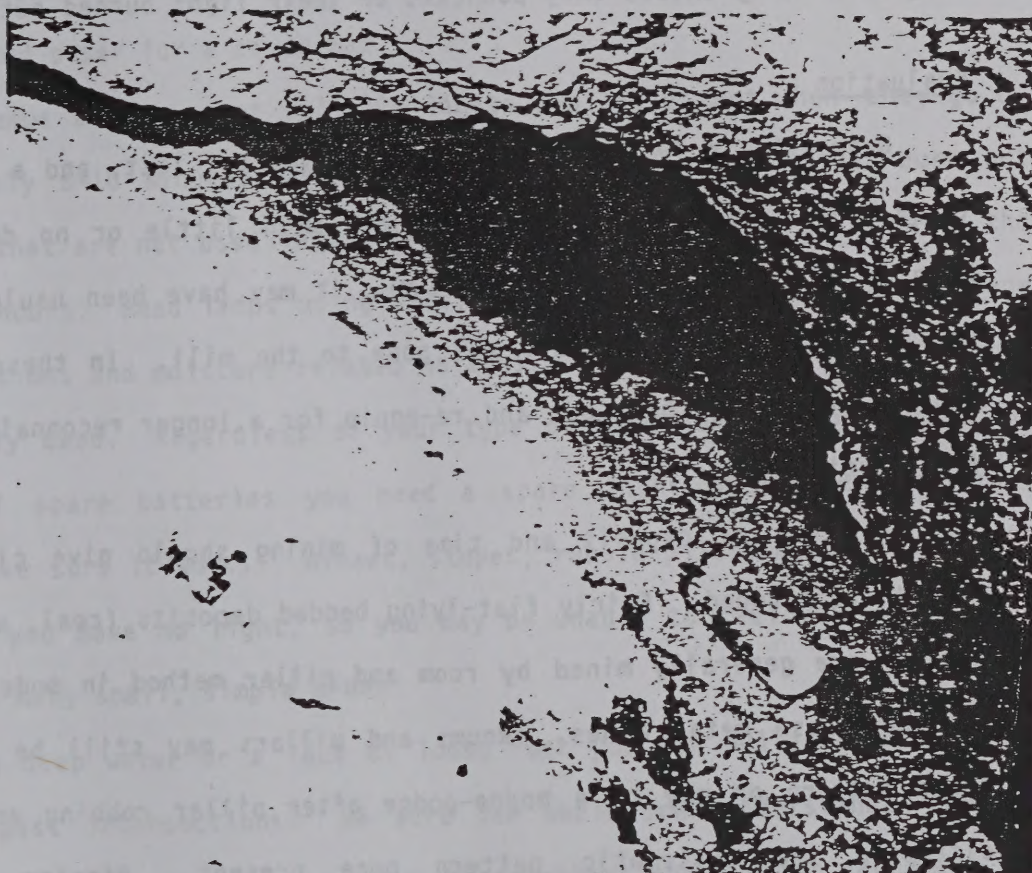


Figure 68.--The left rib swells and flows when wet. When dry it is stable. This swelling ground is a highly altered dike. This is an example of slaking.

and pillar mine or a multi-level mine with more than one usable route between levels could cause confusion, but when laid out rationally these present little problem to one who understands mining methods and has the ability to recognize geological features underground.

In the three mines I have seen where a person could get lost, it should only be briefly unless they panicked or their light burned out.

Evaluation

Generally, only in a large mine can you get lost, and a large mine has a large dump. We have found large mines with little or no dump--it may have been in a stream bed and washed away, it may have been hauled away for road construction, or it may have all gone to the mill. In these rare instances you may need to go back out and re-equip for a longer reconnaissance trip than first anticipated.

The type of deposit and time of mining should give clues to what to expect underground. Fairly flat-lying bedded deposits (coal, uranium, gypsum, potash) are generally mined by room and pillar method in modern practice, as are some base metal mines. Rooms and pillars may still be a neat checker board pattern or may be a hodge-podge after pillar robbing and local caving disrupted the systematic pattern once present. Dipping vein deposits generally are not a problem unless there are several levels or more than one vein. A flat-lying vein would have been mined like a bedded deposit. Deposits localized along intrusive contacts and replacement deposits in limestone or dolomite will be irregular and mining may have no obvious pattern, particularly in older mines. Some stopes are too large for even a good light to shine across, so you can get turned around easily in these.

places it may be difficult to tell a working from a water course, and we have seen a water course used for a manway.

Procedures

Once you realize you have the potential to get lost you make preparations to avoid that. You need to have a back-up light always, trail marking capability, and paper for a crude map.

Wheat lamps are the most reliable lights available, but when they go out they give only 5-10 minutes between detectable dimming and total burn out. Wheat lamps that are not used regularly do not usually take a full charge that will last 8 hours. Head lamps using D-cell batteries are subject to breakage, loose connections and moisture related outages. New batteries have been found to be totally dead. Regardless of your type of head lamp and/or number and freshness of spare batteries you need a spare light with good batteries. Check and make sure it works. Winzes, stopes, rubble piles, etc., can prevent movement if you have no light, so you may be unable to feel your way out as you could in many small, simple mines.

Barring deep water or a lack of loose rock you can build cairns to mark your route past intersections. Be sure the whole crew understands the code you use. If you know in advance about the problems spray paint can mark your routes unless the mine is too wet for paint to adhere. Chalk will also work in a dry mine. A system that will nearly always work is surveyor's tape. It can be tied to pipe, cairns, or stuck to the rib with small nails. It's very possible that some assortment of these trail markers is already present in places. Using tape and pulling it as you leave will keep you and the next people from getting confused.

Assuming there is work to do after initial reconnaissance, it is helpful to be able to plan that work with a sketch map. All you need to do is take bearings and pace the distance and mark intersections and hazards. It does not need to be drawn to scale, but can be sketched. This is the quickest method of learning your way around.

If you do get lost there are a few generalities that may help. If you came in on a level that had track haulage, and are still on that level, the acute angle formed by intersections should point out unless both passages follow structures, because tracked cars won't turn acute angles. If you came in through running water you may be able to follow the current out. The flow of air should remain constant for several hours at a time if there is detectable air movement. You may get out by going toward or away from it depending on the flow direction.

If your light is out and it's not safe to move because of winzes, rubble or whatever, the best way to signal is to bang on pipe or rail. Banging on rock will carry a little distance, but your voice will carry even less. Use a steady tapping to get them to that point. Use voice signals after the partner is close.

RISK ASSESSMENT

Risk assessment is your best estimate of what will probably happen, and the consequences if your estimate is incorrect. The severity of the consequences will affect the decision of whether to accept the risk. For example: if the consequence is certain death, most individuals would not accept a 50% chance of incurring the consequence, but if the consequence is a boot full of ice water and muddy clothes, a 50% chance of incurring the consequence would be a small deterrent to assuming the risk.

Individuals vary greatly in how they assess risks, and most individuals will have days when they vary from their own norm. Being more conservative is entirely appropriate on the days a person is feeling worried, distracted, physically below par, or mentally tired or stressed. In such conditions, most individual's judgement is not his best, and the conservative approach is appropriate.

A team made up of a happily married parent and a young single person would probably match a person disinclined to accept risks with one who is inclined toward risk taking. In this, or any other situation when the team members have very different assessments of risk, both parties should discuss the situation and try for a mutually acceptable compromise. Failing in this, the most experienced person's opinion should carry the most weight, however no one should go into a situation they feel is threatening.

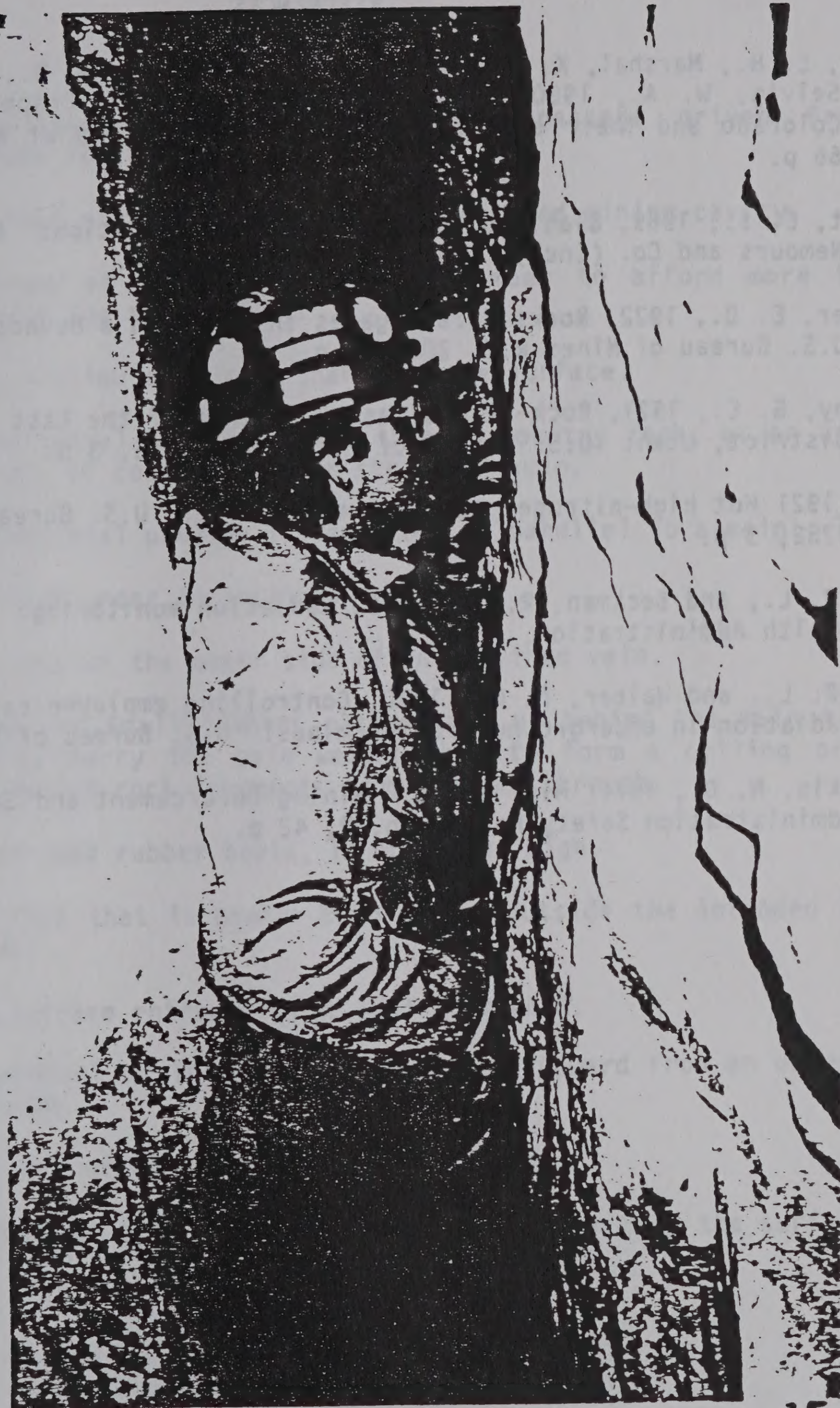
A common question is "Where do you draw the line and say this situation is too hazardous?". Disregarding situations where the risk is obviously too great to accept, only the persons present at the time can hope to make a valid judgement because some of their perceptions will not be conciously verbalized so that a remote judge could get the entire picture. You must use your own judgement of both the degree of risks and the possible consequences of judging incorrectly. If, in you own mind, there is a reasonable doubt that you may suffer the consequence, and if that consequence is worse than temporary discomfort, the only reasonable and proper action is to refuse to take the risk.

CONCLUSIONS

The information that can be gathered from inactive mines is of potentially great value, but entering inactive mines is a hazardous practice.

A variety of possible life-threatening situations will be encountered, and serious injuries can occur by a variety of means. The main hazards have been discussed, but unique situations are always possible (fig. 69).

Knowledge, prudence, careful observations, and a few pieces of equipment will allow a worker to reduce the risks to an acceptable level in many, but not all cases. If there is one hard and fast rule for work in inactive mines it is "When in doubt, chicken out."



25.

Figure 69.--Uncommon hazards exist in some mines. You could get stuck in a stope, particularly if your gear is in the wrong position for the situation.

REFERENCES

Denny, E. H., Marshal, K. L., Fieldner, A. C., Emery, A. H., Yant, W. P., and Selvig, W. A., 1930, Rock strata cases of the Cripple Creek district, Colorado and their effect on mining: U.S. Bureau of Mines Bulletin 317, 66 p.

DuPont, E. I., 1969, Blasters Handbook, Fifteenth Edition: E. I., DuPont de Nemours and Co. (Inc.), Wilmington, Del., 525 p.

Gardner, E. D., 1922, Rocks strata gases in mines in a Nevada mining district: U.S. Bureau of Mines R.I. 2027, 4 p.

McElroy, G. E., 1921, Rock-strata gases in mines of the East Tintic mining district, Utah: U.S. Bureau of Mines R.I. 2275, 3 p.

______1921 Hot high-nitrogen gas in a metal mine: U.S. Bureau of Mines R.I. 2282, 3 p.

Rock, R. L., and Beckman, R. T., 1979, Radiation monitoring: Mine Safety and Health Administration, 75 p.

Rock, R. L., and Walker, D. K., 1970, Controlling employee exposure to alpha radiation in underground uranium mines: U.S. Bureau of Mines, 72 p.

Zabetakis, M. G., 1974, Mine gases: Mining Enforcement and Safety Administration Safety Manual No. 2, 42 p.

GLOSSARY

adit.	A horizontal or nearly horizontal passage driven from the surface for working a mine.
back.	The roof or upper part in any underground mining cavity.
cap.	A piece of wood fitted over a timber to afford more bearing surface for the support.
collar.	The junction of a mine shaft and the surface.
crosscut.	A horizontal passage driven through country rock, at an angle to the dip of country rock or strike of vein.
drift.	A horizontal passage driven along or parallel to a vein.
footwall.	The rock under an inclined vein.
hanging wall.	The rock on the upper side of an inclined vein.
lagging.	Planks or small timbers placed over or behind the main timbers, not to carry the main weight, but to form a ceiling or wall, preventing rock fragments from falling through.
muckers.	Steel-toed rubber boots, 12 or 16 in. high.
overbreak.	The rock that is broken by blasting outside the intended line of break.
portal.	The surface entrance to an adit or tunnel.
raise.	A vertical or inclined passage driven upward from an underground passage.
rib.	The wall of an underground mining cavity.
shaft.	A vertical or steeply inclined passage down from the surface.
sill.	The floor of an underground mining cavity.
stope.	An opening from which ore was removed.
wheat lamp.	Miners cap lamp with rechargeable battery.
winze.	A vertical or inclined passage driven downward from an underground passage.